EXHIBIT 4

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
SHERMAN DIVISION

MOBILITY WORKX, LLC, Plaintiff, v. CELLCO PARTNERSHIP D/B/A/ VERIZON WIRELESS, INC., Defendant.	JURY TRIAL DEMANDED

UPDATED EXPERT REPORT

By Dr. Sukumaran Nair

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I. INTRODUCTION

1. My name is Dr. Sukumaran Nair. I am a U.S. citizen, currently residing in Dallas, Texas. I have been retained by Mobility Workx, LLC ("Mobility") as an expert witness in the above-identified patent litigation with Cellco Partnership d/b/a Verizon Wireless, Inc. ("Verizon" or "Defendant").

2. I understand that in this litigation Mobility has asserted that Verizon infringes United States Patent Nos. 7,231,330 (the "'330 Patent") and 8,213,417 (the "'417 Patent"). I may collectively refer to the '330 and '417 patents as the patents-in-suit or the asserted patents. It is my understanding that Mobility asserts that Defendant infringes claims 1, 3, and 4 of the '330 Patent and claims 1, 4, and 7 of the '417 Patent, which I may refer to as the "Asserted Claims."

3. My educational background, career history, publications, and other relevant qualifications can be found in my Curriculum Vitae attached as Exhibit A to my Declaration.

4. This report summarizes my qualifications to provide the opinion expressed herein and provides a complete statement of the opinions I currently hold, along with the factual basis and reasoning as of May 16, 2019. I understand certain discovery issues remain pending and further information may become available. To the extent additional information becomes available or new events transpire that may affect my opinions, I reserve the right to revise and/or supplement this report.

5. In addition, I may review, analyze, critique, and/or prepare a rebuttal report and/or reply report in response to expert reports and/or rebuttal reports, if any, submitted by Verizon in this matter. References in this report to documents and testimony are meant to provide examples of supporting information but are not intended to be a comprehensive or exhaustive list of all known support.

II. QUALIFICATIONS AND EXPERIENCE

6. A detailed record of my professional qualifications, including the patents on which I am a named inventor and the academic and professional publications on which I am an author, is set forth in my curriculum vitae attached to this report as Exhibit A.

7. In summary, I obtained my Bachelor of Science in Electronics and Telecommunication Engineering from the University of Kerala, India in 1984. I then received a Master of Science and a Doctorate in Electrical and Computer Engineering from University of Illinois in 1988 and 1990, respectively.

8. Since 1984, I have either worked as an engineer or in academia.

9. In 1984 to 1985, I worked as an engineer for the Indian Space Research Organization. As part of my job for the Indian Space Research Organization, I worked on designing and building a telemetry payload and worked on vibration testing space-craft devices and payloads.

10. When I began my Master of Science studies at the University of Illinois in 1986, I took on a position as a Research Assistant and worked in that role from 1986 to 1990. In that role, I Coordinated Science Lab doing research on fault tolerant algorithms, software, and hardware.

11. After obtaining my Ph.D. in 1990, I was hired by the University of Southern Methodist University, where I have worked for the last twenty-nine years. From 1990 to 2005, I worked as an Assistant Professor in the Department of Computer Science and Engineering. However, from January 1996 to June 1996, I was on sabbatical for one semester to the University of Texas at Austin, where I conducted research in the Computer Engineering Research Centre at the University. From 2005 to the present, I have been a full tenured professor at Southern Methodist University in the Department of Computer Science and Engineering. From 2008 to 2016, I also served as the Chair of the Department and I became a University Distinguished Professor in

2015 and have been one ever since. In 2016, I because a Director of the AT&T Center for Virtualization at the University and continue in that roll to this day.

12. Over the last thirty years of academia, my research and teaching have been focused on software centric telecom systems, cloud and network security, and high assurance systems. This work has directly included research that is directly related to mobile/cellular communications. For example, my courses on Networks and Security include detailed coverage of wireless networks including GSM, 3GP, 4GP/LTE, and 5G. Currently one of the major research focuses at the Center is on 5G technology and its deployment and applications.

13. In addition to my work in academia, I have been retained as an expert to assist with a variety of patent infringement and validity related issues, including being retained as an expert nine patent litigations and one patent reexamination. Four of the matters for which I have been retained as an expert have involved various aspects of wired / wireless communications networks. Most recently, from 2013-2015, I was retained as an expert in a case involving intellectual property infringement in wireless technology.

III. PREVIOUS TESTIFYING EXPERIENCE

14. A list of all other cases in which, during the previous 5 years, I have testified as an expert at trial or by deposition can be found in my Professional Services Overview attached to this report as Exhibit A. Most recently I was deposed at the USPTO in 2012, in a patent re-examination case.

IV. COMPENSATION

15. I am being compensated for my services at a rate of $250 per hour. I am being separately reimbursed for any out-of-pocket expenses. My compensation does not depend in any way on the outcome of this litigation or the testimony or opinions that I express.

V. MATERIALS CONSIDERED

16. My opinions are based on my experience in this field, and are necessarily formed by my own experiences, materials I have read over the years, and discussions I have had with colleagues during my career. In addition, I have reviewed and considered the materials identified in Exhibit B in forming my opinions discussed herein and I have had discussions with Drs. Helal and Hernandez regarding the patents-in-suit, the genesis of the inventions claimed therein, the asserted claims of the patents in suit, and the network architecture and operation of various generations of cellular networks, particularly LTE networks.

VI. USE OF DEMONSTRATIVES

17. I expect that I may refer to the materials listed in Exhibit B, and those specifically cited in this report, as well as representative photographs, charts, graphs, schematics, layouts, animations, and/or models at trial and deposition that I may create to support and explain my testimony and opinions set forth herein. I may also use such materials to explain the inventions, patents, relevant technology areas, and/or other matters that may assist the Court and jury in understanding the technology and asserted patents. As of the date of this report, except as included herein, I have not created any such demonstratives.

VII. SUMMARY OF SUBJECT MATTER OF TESTIMONY AND PRINCIPAL OPINIONS

18. It is my understanding that Mobility asserts that Defendant infringes claims 1, 3, and 4 of the ’330 Patent and claims 1, 4 and 7 of the ’417 Patent.

19. I understand that Mobility asserts that certain emulation equipment that Defendant uses (“Verizon Emulator”)—and which Verizon requires all mobile equipment manufactures to use to test the operability of their mobile equipment with the Verizon LTE Network—infringes the

Asserted Claims of the ’330 Patent. I understand that Mobility asserts that Defendant’s LTE Network infringes the Asserted Claims of the ’417 Patent.

20. It is my opinion that Verizon’s Emulator (as defined more specifically below) directly infringes as least the Asserted Claims of the ’330 Patent.

21. It is also my opinion that Verizon’s LTE Network (as defined more specifically below) directly infringes at least the Asserted Claims of the ’417 Patent.

22. It is my opinion that Verizon actively induces mobile equipment manufacturers (who provide mobile devices for use on the Verizon LTE Network) to infringe at least the Asserted Claims of the ’330 Patent. As part of this opinion, it is my opinion that these mobile equipment manufacturers (who provide mobile devices for use on the Verizon LTE Network) directly infringe at least the Asserted Claims of the ’330 Patent.

23. It is my opinion that Verizon actively induces its customers and end users (who use the Verizon LTE Network) to infringe at least the Asserted Claims of the ’417 Patent. As part of this opinion, it is my opinion that Verizon’s customers and end users (who use the Verizon LTE Network) directly infringe at least the Asserted Claims of the ’417 Patent.

VIII. THE BACKGROUND OF THE INVENTORS AND THEIR INVENTIVE CONTRIBUTIONS TO THE MOBILE COMMUNICATION INDUSTRY

24. I understand Dr. Helal is a U.S. citizen, currently residing in Lancaster, Lancashire County, England, the United Kingdom. Born in Suez, Egypt, I am informed he earned his BE and ME degrees summa cum laude in Computer Engineering and Automatic Control from Alexandria University, Egypt, in 1982 and 1985, respectively. I am also informed that Dr. Helal earned his MSc and PhD degrees in Computer Sciences from Purdue University in 1989 and 1991, respectively.

25. I am informed that Dr. Helal has been a Professor at the Computer and Information Science and Engineering Department at the University of Florida since 1998, and is currently on leave to Lancaster University, UK.

26. I understand Dr. Hernandez is a U.S. citizen, currently residing in Boca Raton, Florida. I am informed that in 1995, he graduated with a Bachelor of Science in Electronics Engineering from the Costa Rica Institute of Technology. Shortly after graduation, I understand he joined the Central American Telecommunications Commission (COMTELCA) and was in charge of the creation and planning for their Internet presence. Additionally, during that period (1995-1997), I am informed he also became one of the Internet pioneers in Honduras due to co-founding COMPUNET with his parents in 1996, which happened to be one Honduras's first Internet service providers.

27. In 1997, I understand Dr. Hernandez was awarded a Fulbright scholarship while admitted to the University of Florida ("UF"), Electrical and Computer Engineering Department in Gainesville. In 1999, he completed his Master of Science in Electrical and Computer Engineering at UF and published his Master's thesis "Adaptive Sampling for Network Management."

28. In 1999, Dr. Hernandez was admitted to the Ph.D. program at UF in Computer Engineering where he studied "mobile computing" under the guidance of Dr. Helal. During that time, he investigated the effects of speed on mobile device handoffs.

29. I am also informed that Drs. Hernandez and Helal began working on a project called RAMON or Rapid Mobility Network Emulator.

30. During their research on the RAMON project, I understand that Drs. Hernandez and Helal realized that current simulation environments were inadequate to simulate various mobility

protocols properly. I understand this led Dr. Hernandez and Dr. Helal to conceive of the inventions that ultimately became the subject of the two patents-in-suit, namely:

a. U.S. Patent No. 7,231,330 (the ’330 patent); and

b. U.S. Patent No. 8,213,417 (the ’417 patent)[1]

A. The ’330 Patent

31. I understand that the priority date of the ’330 Patent is at least as early as July 31, 2003, the date when Dr. Helal and Dr. Hernandez originally filed provisional Patent Application No. 60/491,637. The ’330 Patent claims the benefit of the filing date of the ’637 application. (’330 Patent.)

32. The ’330 Patent—entitled “Rapid Mobility Network Emulator Method and System”—was issued by the U.S. Patent and Trademark Office on June 12, 2007. (’330 Patent.) The named inventors on the ’330 Patent are Dr. Hernandez and Dr. Helal. (*Id.*)

33. The ‘330 Patent teaches, among other things, a system and method for emulating mobile network communications. These novel systems and methods disclosed and claimed provide various advantages and benefits. For example, the system and methods provide for the modeling and testing of various mobile network configurations and scenarios. These advantageous results, among others, are achieved by dynamically adjusting the signal reception sensitivity and signal transmission strength of each wireless node and by emulating at least one wireless network node. (’330 Patent.)

[1] I understand that there was also a third patent that resulted from the RAMON project, namely U.S. Patent No. 7,697,508 (the ‘508 patent). I am informed, however, that the ‘508 patent is not currently being asserted against Verizon. The ‘417 patent is a continuation of the ‘508 patent.

34. The subject matter of the asserted claims of the ’330 Patent generally relate to a system for emulating mobile network communications in a packet-switched[2] network. (’330 Patent, Claim 1.)

35. At the time of the invention of the ’330 Patent, there were two distinct worlds: (1) circuit switched systems and public switched telephone networks (or “PSTNs”); and (2) packet-switched communications.

36. These two worlds only merged with platforms like AOL and/or other ISPs where dial-up modems were de facto means for sending packet-data over a PSTN.

37. At that time, emulation and simulation of high-speed mobility were not available, nor was a full streaming session in a fast-moving vehicle.

38. These limitations were mainly due to the following:

a. Lack of the implementation of a technology employing packet-switching of data in a mobile device,

b. Lack of emulation platforms for packet-based systems, and

c. High-latency and reactive protocols generally designed for static devices or devices traveling at extremely slow speeds, such as the speed at which a person might walk.

39. A purely simulation-based approach to study mobility was insufficient to accurately predict the performance of a mobile device because RF conditions were not experimentally

[2] The terms “packet-switched network” and “packet-based network” are synonymous and used interchangeably throughout this report.

computable and not realistic, the simulations were simply ineffective in the creation and analysis of new protocols.[3]

40. Hence a mixture of simulation and real-life scenarios had to be created and that's how the '330 Patent was created to simulate mobile communication around a fast-moving vehicle such as a train.

41. At the time of invention, there was not a single device available or known that could combine packet-based communications, and internet mobility (e.g. Mobile IP) with RF simulations, concomitantly.

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[3] E. Hernandez, S. Helal. Examining Mobile-IP Performance in Rapidly Mobile Environments: The Case of a Commuter Train, IEEE LCN 2001, November 14-16, 2001.

B. The ’417 Patent

42. I understand that the priority date of the ’417 Patent is at least as early as July 31, 2003, the date when Dr. Helal and Dr. Hernandez originally filed provisional Patent Application No. 60/491,436. The ’417 Patent claims the benefit of the filing date of the ’436 application, as well as the intervening ’508 Patent. (’417 Patent.)

43. The subject matter of the ’417 Patent generally relates to “the field of communications and more particularly, to allocation of resources of a communications network for supporting wireless communications.” ’417 Patent, 1:17-19.

44. The ’417 Patent—entitled “System, Apparatus, and Methods for Proactive Allocation of Wireless Communication Resources”—was issued by the U.S. Patent and Trademark Office on July 3, 2012. (’417 Patent.) The named inventors on the ’330 Patent are Dr. Hernandez and Dr. Helal. (*Id.*)

45. The ’417 Patent teaches, among other things, a system for allocation of resources in a communications network for supporting wireless communications. This novel system provides various advantages and benefits. For example, it leads to reduced delays and information losses in wireless communication networks by reducing registration overhead and setup times associated with mobile node handoffs. These advantageous results, among others, are achieved by allocating communication network resources proactively rather than reactively. (’417 Patent.)

46. The asserted claims of the ’417 Patent generally relate to a system for communicating between a mobile node and a communication network (’417 Patent, Claim 1) and a method for speeding handover between a mobile node and a network (’417 Patent Claim 7).

47. In my opinion, the ’417 Patent provides, in general terms, a technical solution to the problem of high latency in situations in which a communication connection is transferred from

one entity (e.g., source base station) to another (e.g., target base station) and in which such high latency resulted in lost packets or interrupted voice connections. The ’417 Patent provides a solution to this problem by, for example, proactively informing the target base station that a mobile node is going to be in the coverage region of the target base station and enabling the target base station to establish resources (e.g., a communications tunnel) so that packets are buffered at the target base station for the arrival of the mobile device node within the coverage region of the target base station.

48. The ’417 Patent describes various inventions, including systems, apparatus, and methods, for proactively allocating wireless communication resources. The inventions improve traditional hard handover procedures by executing a series of signaling and communications through two sets of pairing: pairing a ghost-foreign agent with a foreign agent; and pairing a ghost mobile node with a mobile node. The pairings and resulting signaling and communications execute various tasks, such as IP message transmission, resource allocation, mobility initiation, and registration. The creation and use of the pairings may be based on the physical location of a mobile node and/or the distance a mobile node is from a foreign agent. The physical location and/or distance may be indicated by the signal strength the mobile node detects from the foreign agent, among other things. As a result, handover latency is reduced improving LTE system performance that, in turn, enables VoLTE and other applications that demand low latency.

49. In 2002, there were only a handful of packet data service providers, including iDEN (Integrated Digital Enhanced Network) and DECT (Digital Enhanced Cordless Telecommunications) providers.

50. In the same time frame, most of the research on high-speed mobile-internet to create the next generation wireless system was theoretical, or experimental in nature. Often, these efforts

were confidential. At the time, most of the mobile phones, including Ericsson and Nokia models, did not have the computing power to load a full IPv4 stack. Instead, they were supporting IP stacks with limited features.

51. Other supported protocols/standards at that time included ATM (Asynchronous Transfer Mode), X.25, TDM-access for the WCDMA networks and STM (Synchronous Transfer Mode).

52. Ethernet and other packet communications offered random access to packets. Further, ethernet, for example, had no guaranteed bandwidth.

53. Telecommunication engineering and IP networking were not conjoined as we see it today with LTE and 4G. In fact, Packet switched networks and Circuit switched networks were not seen as competing solutions, but solutions for two different worlds.[4] Dr. Hernandez, however, came from a packet-switched Internet world, which allowed him to envision an opportunity for combining the two worlds to achieve more effective and robust mobile communications through a packet switched network.

54. Prior to the effective filing date of the '417 Patent, Circuit switching governed all voice communications, while packet switching the data/Internet.

a. Circuit switching: "Circuit switching is characterized by the reservation of bandwidth for the duration of a call. This reservation involves an initial call establishment (set-up) phase using signaling messages, and the release of the bandwidth in a call termination (clear) phase at the end of a call. In modern digital networks, reserved bandwidth means periodically repeating time slots in time division multiplexed (TDM) links,"[5]

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[4] https://www.computerworld.com/article/2593382/networking-packet-switched-vs-circuit-switched-networks.html.

[5] Thomas M. Chen, **From Circuit Switched to IP-based Networks**, Chapter in *Encyclopedia of Multimedia Technology and Networking*, 2nd ed., M. Pagani (ed.), Idea Group Publishing (2008).

b. Packet Switching: "Packet switching may be more natural for data but involves its own challenges. One of the major challenges is quality of service. Statistical multiplexing handles contention by buffering, but buffering introduces random queueing delays and possible packet loss from buffer overflow. Thus, QoS in packet networks is vulnerable to congestion and degrades with increasing traffic loaded"[6]

55. Hence the distinctions between circuit switching and packet-based switching can be derived:

a. Circuits are reserved, with guaranteed bandwidth. In packet switching, resources are allocated statistically, and bandwidth is not-guaranteed. The basic building block of the internet is the IP packet.
b. Voice needs reserved/guaranteed bandwidth, thus had a problem with Internet which uses statistical multiplexing
c. Erlang law was used to compute circuit switched utilizations vs Packet-switched was governed by more sophisticated models that were at that time unknown.

56. The state of the art at the time could not foresee an LTE wireless world where IP-packets replaced circuit switching. Those IP packets with new statistical distributions of delay, and bandwidth could be used in a way that would carry voice and data traffic at the same time.

IX. ONE OF ORDINARY SKILL IN THE ART

57. I understand that a patent is a legal document issued by the United States and written specifically for one of ordinary skill in the art to which the patent pertains. I also understand that it is the role of a court to construe (i.e., interpret) the disputed claim terms of the patents-in-suit,

[6] *Id.*

as one of ordinary skill in the art would so construe the claims. On March 15, 2019, the Court in this case construed the disputed claim terms of the ’330 Patent and ’417 Patent. While I understand that prior to final judgment, a court may revise its claim constructions, I will use the Court’s Claim Construction of the terms as of March 15, 2019, in the analysis here, as set forth below:

X. AGREED AND COURT CONSTRUED CLAIM TERMS

Agreed and ordered terms are reflected in the table below:

Table 1. Markman Order Terms and Resolution by the court

“Ghost Mobile Node” (’417 Patent, Claim 1)	“a node, or a virtual node, that can operate on behalf of the mobile node and that is capable of registering with a foreign agent and allocating resources for the mobile node before the mobile node arrives in the physical area covered by the foreign agent”
“Ghost Foreign Agent” (‘417 Patent, Claim 1)	“a virtual node corresponding to a foreign agent that can make a mobile node aware of the corresponding foreign agent’s presence in a communication network proximate to the predicted future location of the mobile node”
“a ghost-mobile node that creates replica IP messages on behalf of a mobile node” (’417 Patent, Claim 1)	“a ghost-mobile node that copies IP messages on behalf of a mobile node”
“wireless” (’330 Patent, Claims 1, 3, 4)	“without wires or cables, and only through air or vacuum”
“mobile node configured to wirelessly communicate” (’330 Patent, Claim 1)	“a device that sends and receives signals wirelessly”
“wireless network nodes” (’330 Patent, Claim 1)	“an element of a network that sends and receives signals wirelessly”

"a packet-based wired communications network" ('330 Patent, Claim 1)	"a communications network in which packets of data are transmitted through wires or cables"
"Foreign Agent" ('417 Patent, Claim 1)	"a network node on a visited network that assists the mobile node in receiving communications."
"fixedly located" ('330 Patent, Claim 1)	"set at a particular location"
"when the mobile node is located in a geographical area where the foreign agent is not physically present" ('417 Patent, Claim 1)	"when the mobile node is located outside of the region covered by the foreign agent."
"updating, in a mobile node, a location in a ghost mobile node" ('417 Patent, Claim 1)	"updating the ghost mobile node with a location of the mobile node."
"configured to variably adjust wireless communication characteristics" ('330 Patent, Claim 1)	"configured such that the controller can cause the wireless network nodes to adjust wireless communication characteristics of the wireless network nodes."
"communicatively linked" ('330 Patent, Claim 1)	"capable of transmitting and receiving signals via an interface.
"without changing operating parameters of said at least one mobile node" ('330 Patent, Claim 1)	"plain meaning"

(Court's Claim Construction Order, Dkt. 74.)

58. I understand that an analysis of a patent, including an infringement analysis, requires viewing the patent and all terms from the perspective of one of ordinary skill in the art of the field of the invention. The '330 Patent pertains to development and testing of wireless communication networks and components. This includes the "emulation of wireless networks" used in the mobile communications industry. '330 Patent, at abstract & 1:14-16. One of

ordinary skill in this art would have a Bachelor of Science degree in electrical, electronics or computer engineering, or even mechanical engineering if there is sufficient training in electrical, electronics, telephony or computer engineering within such degree. In addition, one of ordinary skill in the art will have at least two or three years of experience in systems testing in wireless communications. Increased experience may make less relevant the specific education, as the experience in wireless communication is the key ingredient in one of ordinary skill. I have a PhD degree in engineering that included studies in computer programming and electrical engineering and related engineering courses. I also have extensive experience in the wireless network communications industry, including in the testing and development of wireless devices. My experience would include that of one of ordinary skill in the art.

59. I will apply the claims as interpreted by the Court (and the remaining terms not so defined or agreed upon by the parties, according as I believe one of ordinary skill in the art would so understand those terms) to the testing methodologies and requirements set forth by Verizon to test and validate all mobile and wireless communications equipment in their network. It is my opinion that Verizon's device and methods infringe both literally and under the doctrine of equivalence, as set forth below.

XI. THE BACKGROUND AND IMPORTANCE OF THE '330 PATENT: NO VIABLE ALTERNATIVE

60. I have reviewed Mobility's production submitted to this court wherein they described their activities leading to the invention of the '330 Patent. I have also talked with Dr. Helal and Dr. Hernandez on this subject in the presence of their attorney. Dr. Helal and Dr. Hernandez, while at the University of Florida, researched ways to develop testing and development systems for the mobile network communications industry that would accurately, quickly, and

inexpensively create stable and reliable wireless communication in real-world, challenging, conditions. Such conditions often include a mobile phone traveling at high speeds in a vehicle, zipping by cell towers (base stations) through difficult terrain. They reported their efforts in surveying the literature as to what was available in the industry to emulate such conditions so that they could improve the components of the mobile communications network and the network itself. They reported finding no tool available to emulate the entire network, and therefore they proceeded to invent a tool for that purpose.

61. This is consistent with my survey as I could not find any products available in the early 2000s that could emulate an entire mobile communications network in real-time and allowed for the emulation of a mobile phone in motion within the network. In other words, in my view, the '330 Patent represents the first invention in this subject matter and is not an incremental improvement on someone else's invention in the space.

62. I understand that the law calls patents that disclose break-through inventions "pioneer patents," which I understand the U.S. Supreme Court long ago defined to mean "a patent covering a function never before performed, a wholly novel device, or one of such novelty and importance as to mark a distinct step in the progress of the art, as distinguished from a mere improvement or perfection of what has gone before." *Boyden Power-brake Co. v. Westinghouse*, 170 U.S. 537, 569, 18 S.Ct. 707, 723 (1898). Using this definition, the '330 Patent qualifies, in my opinion, as a pioneer patent.

63. Indeed, the '330 Patent discloses and claims a full-fledged system for emulating a modern mobile communications network, providing a tool to:

- Model RF channel conditions
- Model Packet-based communications
- Model Protocol performance in a realistic fashion
- Real-time Emulation as opposed to simulation

- Real-World devices, protocols, and tools can be used in the invention

64. In my opinion, there were no viable alternatives to the patented invention in the ’330 Patent at the time that Verizon could have implemented during the 2010-2019 timeframe.

65. The unavailability of alternatives, which provided the same or similar emulation functionality and benefits, as does the ’330 Patent at the time of Verizon’s first infringement, has become even more pronounced with the increased sophistication of mobile phones.

66. The increased complexity of mobile devices and applications (e.g. 4G, MIMO, 5G, Mobile Applications, VoLTE) require advanced testing tool like the ’330 Patented invention.

67. The patent covers the emulation of the entire mobile communications network (packet-based), including real time emulation of mobility within such network, and the only alternative for testing and development of mobile phones would be to use a non-emulated manual approach.

68. Before the ’330 Patented invention came to be, a company like Verizon would have no choice but to test and design its mobile phones through a time-consuming, difficult to reproduce, inaccurate, and expensive manual method, often called a “Drive Test.”

69. In the case of Verizon Network, Verizon ran the “Can you hear me now?” commercial for over a decade, that symbolizes and interprets the true nature of “Drive Testing.”

70. This manual method involves engineers with sensitive test equipment driving in a vehicle through the city and countryside taking measurements and trying to determine from this how best to develop the cell phones, cell phone firmware, and the network, so that the wireless communication would be clear and stable. The manual Drive Test method, however, is not only expensive and time intensive, it was also inaccurate as they cannot cover myriad of changing variables in the real-world environments.

71. Indeed, the complexity of today's modern cell phones and the numerous features and applications that they often embody make any manual test method inadequate in identifying and resolving the issues that mobile phones and the mobile phone networks routinely must contend with. Yet, failure to conduct accurate tests could result in poor cellular phone performance and dropped calls which in turn will lead to company embarrassment and lost market share in the demanding consumer market.

72. Dr. Helal and Dr. Hernandez fulfilled this need and solved these problems with the ’330 Patent, which was assigned to University of Florida Research Foundation (UFRF). The patented invention is a system (and method) that emulates the wireless communications taking place in a real-world Drive Test – all in the control of a laboratory. The invention emulates the complete mobile communications network in real time, including (a) mobile phones traveling, virtually, throughout the network, (b) simulated cell phone towers (base stations) and simulated data networks used in the mobile communication network, and (c) the resulting wireless communications and wireless communication characteristics that would result in the real world. Through this invention, engineers are able to accurately find defects and errors that cell phones would face in the real world, correct them in the laboratory through firmware revisions, and thus produce stable and reliable devices and wireless communication. The invention has the advantage of being able to do this at a fraction of the cost and time thus allowing better phones to be sold by Verizon and better service perceived by their customers.

XII. INSIGHTS FROM THE FILE HISTORY OF THE ’330 PATENT

73. I have examined the file history for the ’330 Patent to see what insights it provides to the invention. In October 2006 the examiner issued the first office action, which was a non-final rejection of the claims in light of one prior art reference in particular: U.S. Patent No. 6,735,448 (Krishnamurthy). In January 2007, the applicants responded to the examiner by amending some of the claims and distinguishing the applicants’ invention over the cited prior art. The applicants emphasized that their invention pertains to a “system for emulating mobile network communications.” This notion is found in the preamble of each independent claim of the ’330 Patent.

74. The applicants emphasized that the invention is designed to "variably adjust wireless communication characteristics," emulate certain attributes of a packet-based wired communications network, and the system working together to emulate wireless communication conditions experienced by a real-world mobile phone (including one in motion), which can be simulated without changing the operating parameters of the tested mobile phone. *Id.* at 9.

75. The applicants argued that these features of the invention distinguished over the Krishnamurthy cited prior art. Applicants stated: "Krishnamurthy does not simulate different wireless communication conditions experienced by a mobile node . . . without changing any operating parameters of the mobile node itself." *Id.* at 9-10. Applicants further argued to the examiner that Krishnamurthy's was an ad-hoc network where each component of the network was mobile (such as might be the case in a platoon of soldiers carrying their entire communications network components with them on the battlefield). *Id.* at 12. Applicants argued that their invention, however, included fixedly-located wireless network nodes (which the judge has interpreted to mean set at a particular location). This distinction helps identify the invention to a more traditional commercial mobile communications network where there are fixed base stations/cell towers in set geographical locations connected by large transmission lines or mechanisms.

76. With these clarifications and arguments by the applicants, the examiner allowed the claims (as amended) in February 2007. As seen on the face of the patent, the patent issued on June 12, 2007.

77. The file history for the '330 Patent will be further referenced in my analysis below for certain of the claims as appropriate.

XIII. THE INFRINGEMENT ANALYSIS GENERALLY

78. I understand that the law forbids someone from infringing on a patent claim issued by the United States. I also understand that a device literally infringes on a patent claim when each of the claim limitations "reads on" or is found in the accused device or in the accused method practiced by the infringer.

79. I understand that even if one or more limitations are not <u>literally</u> present, the device may still infringe a claim if <u>equivalents</u> of those limitations are present. I understand that to infringe under doctrine of equivalents, any differences between the claimed invention and the accused product must be insubstantial. I understand that one way of proving that is to show for each limitation of the claim that the accused product "performs substantially the same function in substantially the same way with substantially the same result as each claim limitation of the patented product." A factor to consider in this analysis is whether one of ordinary skill in the relevant art would understand a device covered by the patent to be interchangeable and an ordinary substitute with a device accused of infringement under the doctrine of equivalence. If one of ordinary skill in the art would consider the two components interchangeable, that would likely suggest there is equivalence.

80. I understand that a patent infringement analysis requires a two-step analysis. First, a court determines the scope and meaning of the patent claims asserted. Second, the claims are then compared to the allegedly infringing device or method. I will compare the claims to the accused Verizon's methods and systems to reach my conclusions herein.

81. Mobility Workx, LLC contends that every limitation of Claims 1, 3, and 4 ("Asserted Claims") of U.S. Pat. No. 7,231,330 ("330 Patent" or "Patent-in-Suit") is literally present and infringed by Defendant's LTE network ("Accused Product").

XIV. THE ACCUSED SYSTEM AND METHOD

82. As set forth in documents published on Verizon's website, Verizon has created the "Open Network Development:"

> Verizon Wireless Open Development (OD) is the company's program designed to allow and encourage the development community to create new products, applications and services beyond what Verizon Wireless offers in its portfolio and bring these to the marketplace on the Verizon Wireless network[7]

83. Based on my review of these documents, Verizon requires all devices that are accepted into the "Verizon Wireless Network" to meet a series of requirements that implement the '330 Patent. As explained in Verizon's Open Network Development documents:

> All devices shall successfully pass this test plan per the Verizon Wireless LTE 3GPP Band 13 Lab Conformance Test Plan and in accordance with the Verizon Wireless LTE 3GPP Band 13 Device Conformance Test Process. Prior to testing, Verizon Wireless strongly recommends that all devices pass 3GPP standard RF conformance per 3GPP TS 36.521-1: Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing.[8]

84. The process used for Verizon to accept all devices into their network (in Figure 1) is as follows:

[7] https://opendevelopment.verizonwireless.com/faqs.
[8] LTE Band 13 Data Throughput _Test_Plan_February2018, pg 16.

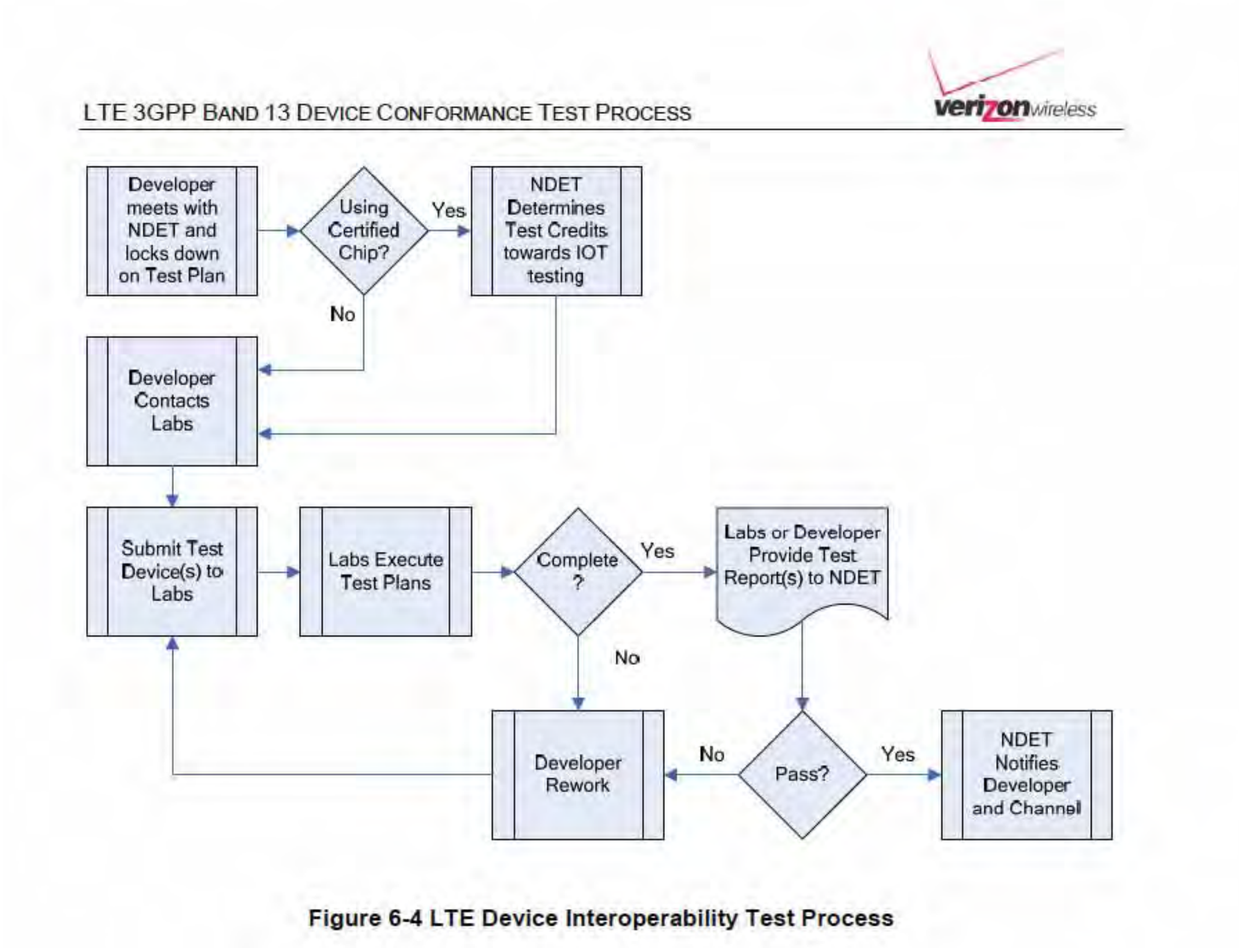

Figure 1. Test Plan LTE Interoperability by Verizon[9]

85. As shown, all manufacturers and vendors from mobile phones, tablets, iOT devices, must meet the requirements set forth in the requirement documents.[10]

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[9] MWVZ00001386.
[10] MWVZ00002714.

1 Introduction

Verizon Wireless requires all devices designed to operate on the Verizon Wireless LTE 3GPP Band 13 network to meet Verizon Wireless network access requirements as detailed in the Verizon Wireless LTE 3GPP Band 13 Network Access Device Requirements. [1]

This publication is part of Verizon Wireless' compliance with the FCC's rules for 700 MHz C Block (47 C.F.R. § 27.16), as explained in the FCC's Second Report and Order in WT Docket No. 06-150, "Service Rules for the 698-746, 747-762 and 777-792 MHz Bands" released on 2013.

In this document, the terms LTE (Long Term Evolution) and E-UTRA (Evolved Universal Terrestrial Radio Access) are considered equivalent. Final Form Factor device and HOST DEVICE should be equivalent.

86. Additionally, Verizon specifies the equipment to be used for testing in its Open Development Network Specifications (MWVZ00000001-MWVZ00002719) (hereinafter "Verizon ODN Spec") and the list of equipment for to be used is shown at MWVZ0000001-MWVZ00000023 in the ODN Spec.

87. Among those requirements included in the Verizon ODM Spec are the following:

a. Testing with Alcatel-Lucent (Nokia) and Ericsson equipment is required. [11]

6.5 LTE Device Field Test Process

The LTE Field Testing is performed in a field environment using live Verizon Wireless LTE Networks. The LTE_DEVELOPER shall test the device in two markets, one where each of the two Verizon Wireless LTE RAN Infrastructure Vendors' (Alcatel-Lucent and Ericsson) equipment is deployed.

GCF Field Test certification is still under investigation by Verizon Wireless.

b. The LTE Device Field Test Process has entrance criteria and only devices passing this stage will be provisioned and can start connecting to Verizon's network.

[11] MWVZ00001383.

6.5.1 **LTE Device Field Test Process Entrance Criteria**

The LTE_DEVELOPER may only enter this stage after successfully passing the Safe For Network Testing (see Section 5), having the IMEI's of the test devices entered into the Verizon Wireless device database (please refer to the process documents for the distribution channel utilized for this LTE_DEVICE to obtain the process to enter IMEI's into the Verizon Wireless device database)

The LTE Safe For Network Test Plan is a subset of the LTE Lab Conformance Test Plan. If the LTE_DEVICE has passed the LTE Lab Conformance Test Process (see Section 6.4), then the LTE_DEVELOPER may use these results in place of the LTE Safe For Network Test Process.

XV. COMPARISON OF THE ACCUSED SYSTEM AND METHOD TO THE CLAIMS OF THE ʼ330 PATENT

88. It is my opinion that the System Simulator and the processes presented in the Verizon ODN Spec at MWVZ00000001-MWVZ00002179 ("the Verizon Emulator") infringes the asserted claims of the '330 Patent. I will show this using the Court's construction of the claim terms and the agreed constructions by the parties.

Claim 1	BASIC OPINION
Preamble: A system for emulating mobile network communications, comprising:	Verizon has shown that all requirement documents indicate the use of a Network Device Evaluation Lab (NDET) where equipment from ANITE, ROHDE SCHWARZ, and others is used to emulate and simulate the network. The system consists of emulated networking elements with the objective to test handover, antenna performance, data performance, and many test cases. This element is satisfied.

A. Discussion on Claim 1 of the '330 Patent

1. Element 1 Discussion

89. As shown, all manufacturers and vendors from mobile phones, tablets, IOT devices, must meet the requirements set forth in all the requirement documents.

90. An "emulator," "emulating" was not a construed term and thus is plain and ordinary meaning to one of ordinary skill in the art applies. In my opinion, one of ordinary skill in the art understands an emulator to be "a system or device (either hardware, software, or both) that

imitates, models or simulates the conditions, acts or functions of a real-world event, system, device, or condition." Further a person of ordinary skill in the art would understand emulating to mean "the act of imitating, modeling or simulating the conditions, acts or functions of a real-world event, system, device, or condition."

91. With this understanding of the word "emulating" as used in the preamble, there is no question that systems used by the NDET emulate mobile network communications in an LTE mobile communications network.

92. The use emulator and simulator terminology is pervasive across the documentation required by Verizon as presented at MWVZ00000083 of the Verizon ODN Spec.

Procedures (Step 1)

The network simulator is configured for signal conformance testing as described in Section *Test Equipment Configuration* with the exception cited in section 5.2A.5 in 36.508 for feICIC and powered on. The device (UE) under test is then connected to the network simulator. After the UE is powered on, acquired and synchronized to the network and already has an internet PDN connection established, UE is in RRC connected mode according to T0 condition in table below. The following procedures should be followed.

UE is on a Pico cell, provides measurement for another Pico cell

St	Procedure	Message Sequence	Verdict

1	The TE simulator transmits an *RRCConnectionReconfiguration* message with serving cell measurement restriction pattern (*measSubframePatternPCell*) on Cell 1 to setup intra frequency measurement. The pattern is what Cell2 uses as in table below for T1. The TE simulator applies OCNG signal ~~according to~~ PCell measurement restriction pattern (on behalf of Cell 2). The TE simulator sets up A2 threshold in Cell1 for RSRQ to -3db in the associated *measObjectEUTRA* IE. The TE simulator changes Cell 1, Cell 2 and Cell 3 parameters according to the row "T1" in table below.	ß	*RRCConnectionReconfiguration*	N/A

Procedures (Step 1)

The network simulator is configured for signal conformance testing as described in Section *Test Equipment Configuration* and powered on. The device (UE) under test is then connected to the network simulator. After the UE is powered on, acquired and synchronized to the network, the following procedures should be either initiated by the UE or performed in response to messages received by the UE.[12]

93. Finally, I understand that the word "comprise" in the preamble has special meaning in patent law, i.e., including, but not limited to. Thus, the preamble recites that the system for emulating mobile network communications must "comprise" specified elements, i.e., the invention covers a system with at least the listed elements, although it would also cover a system with the specified elements in addition to other elements. Verizon's test cases and systems has each of the recited elements as shown below.

Element 1 of Claim 1: a plurality of fixedly-located wireless network nodes configured to variably adjust	Multiple Wireless Network nodes are used for testing several use cases, for instance Band 13 Testing, IMS testing, and others require the use of several eNodeBs communicating packet data while adjusting power levels in Cell #1, #2, and #3.

[12] MWVZ00001783.

wireless communication characteristics;	There are controllers used to change and modify the RSRP (or signal strength), Fading, and noise (AWGN – Additive White Gaussian Noise) levels in the Requirements documents. This element 1 of claim 1 is satisfied.

94. The ODN Spec document includes systems with multiple cells as shown at MWVZ00000073:

Table 2.4.25. RSRQ intra-frequency accuracy test parameters for Test 4.

Parameter	Unit	Cell		
		#1	#2	#3

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95. The cell configuration is presented in "LTE 3GPP Band 13 Supplementary RRM Conformance Test_Plan_February2019.pdf" and the Verizon ODN Spec at MWVZ00000031-00000082.

96. In this document on ppg. 9, 10, 11, and 12 a series of configurations of multiple cells displaying a "plurality" of cells are depicted, meaning 2 and 3 cell configurations (*See* Verizon ODN Spec at MWVZ00000039-MWVZ00000042).

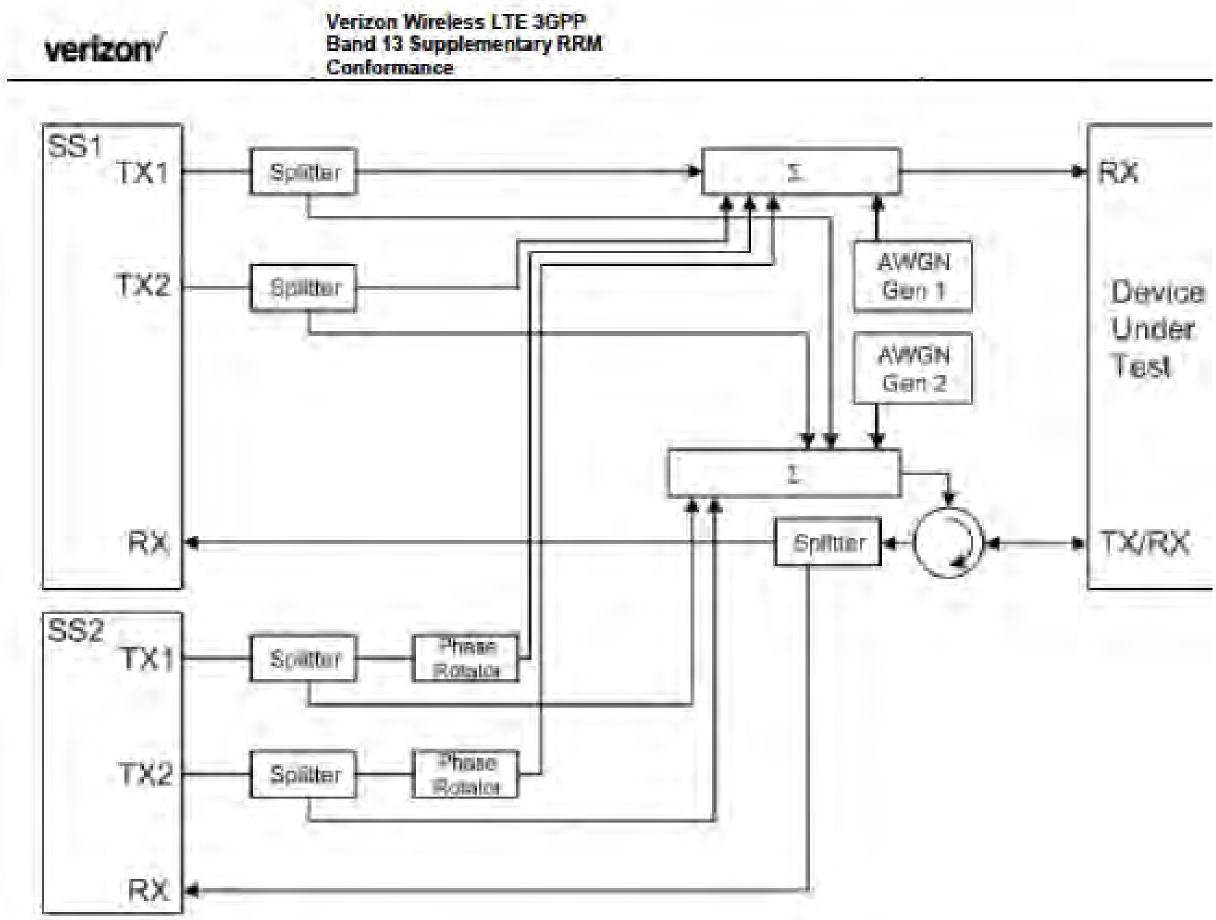


Figure 2 . 2-Cell Configuration for Verizon's Emulator

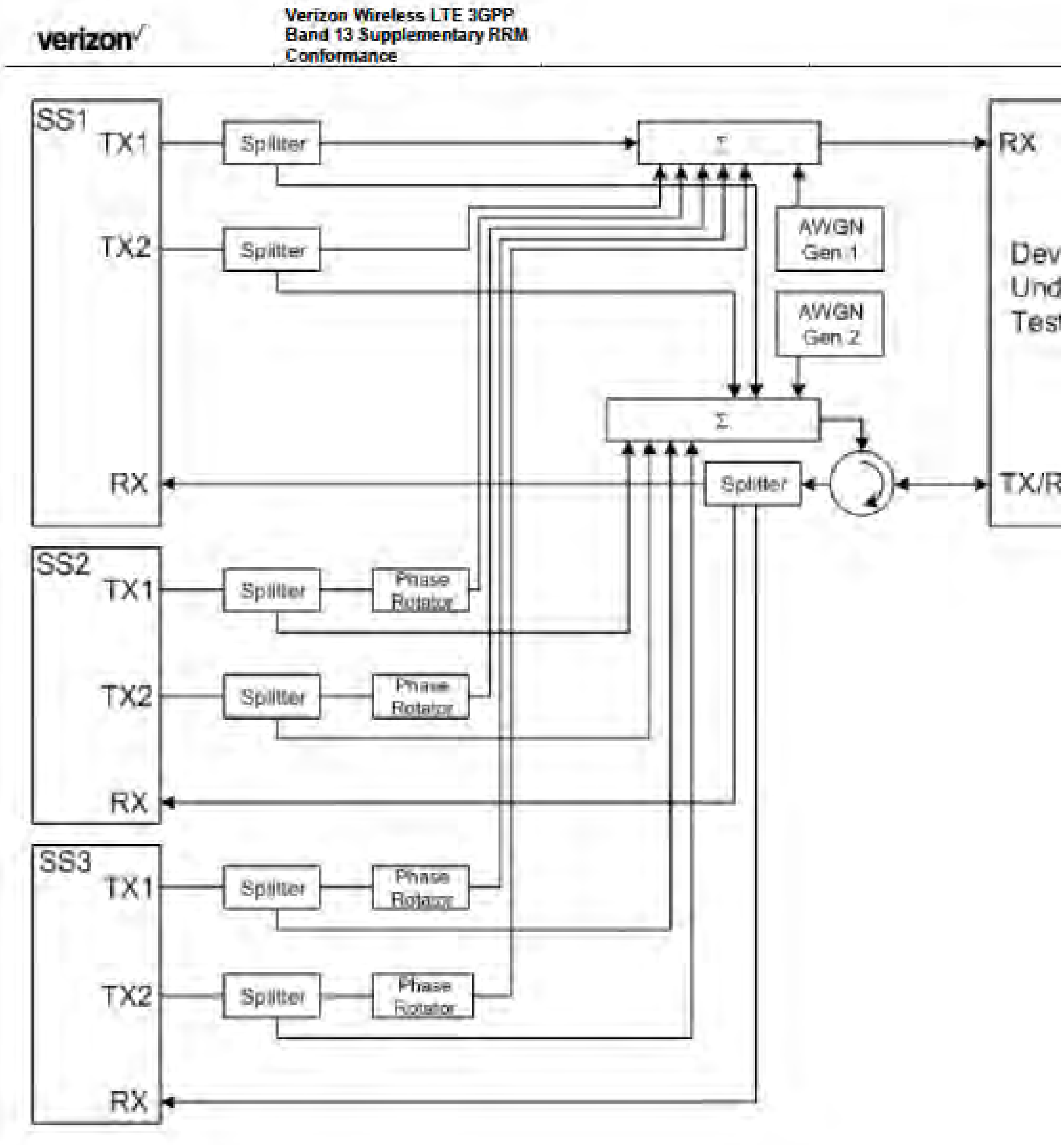


Figure 3. Verizon's 3 Cell configuration for Emulator

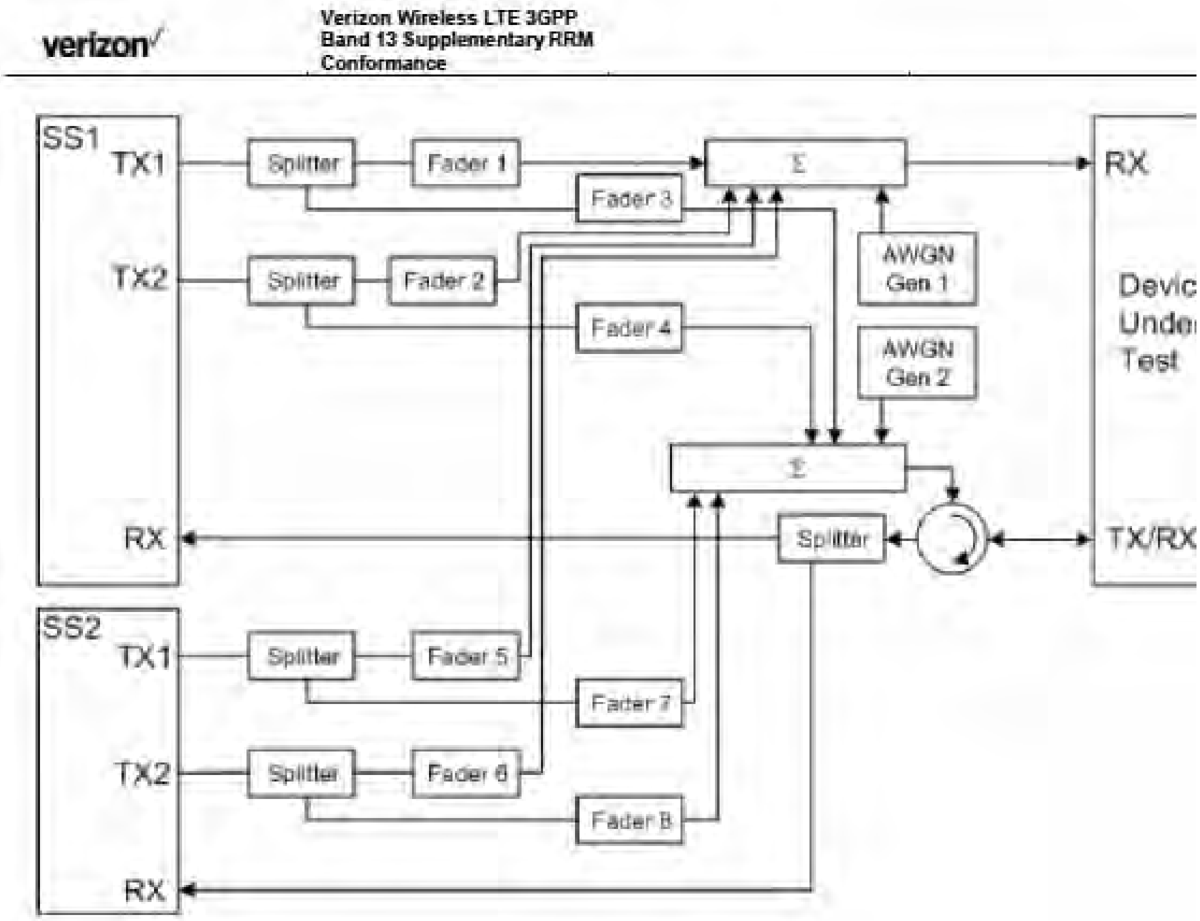


Figure 4. 2 Cell Configuration for Verizon's emulator

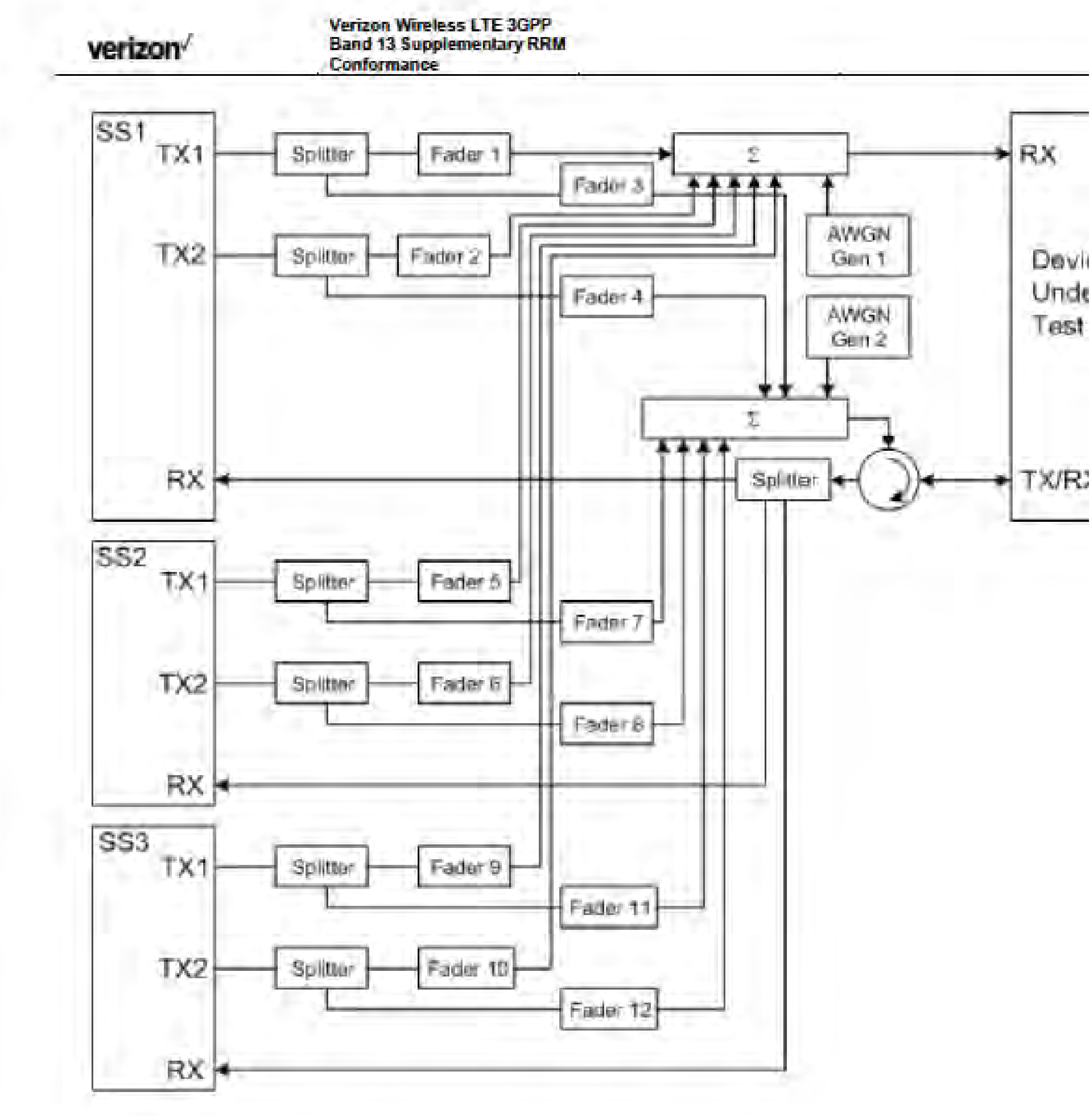


Figure 5. Verizon's 3 Cell Configuration

97. The above figures show how Faders are used to change attenuation and AWGN for injection of noise (or Guassian Noise) to change the Signal to Noise Ratio on the signal generated by either TX1 and/or TX2.

98. The reason for using TX1 and TX2 instead of a single TX is to satisfy MIMO (Multiple Input Multiple Output) 2x2 requirement. However, the set up can also be used for SISO (Single Input Single Output) (1x1). In the following figure, Verizon shows how to use the simulator to test SISO and MIMO configurations.

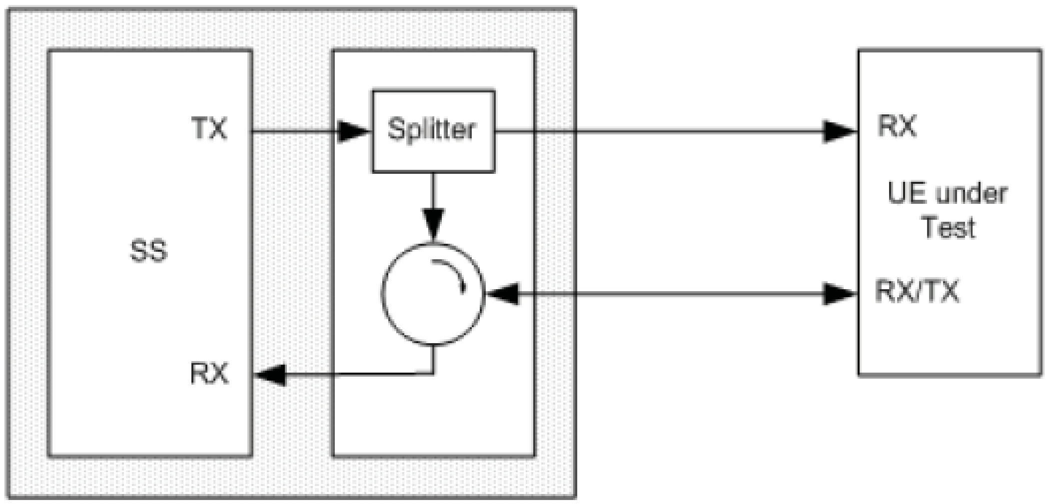


Figure 6. MIMO Configuration, 2 receivers, Transmitter in one line from UE

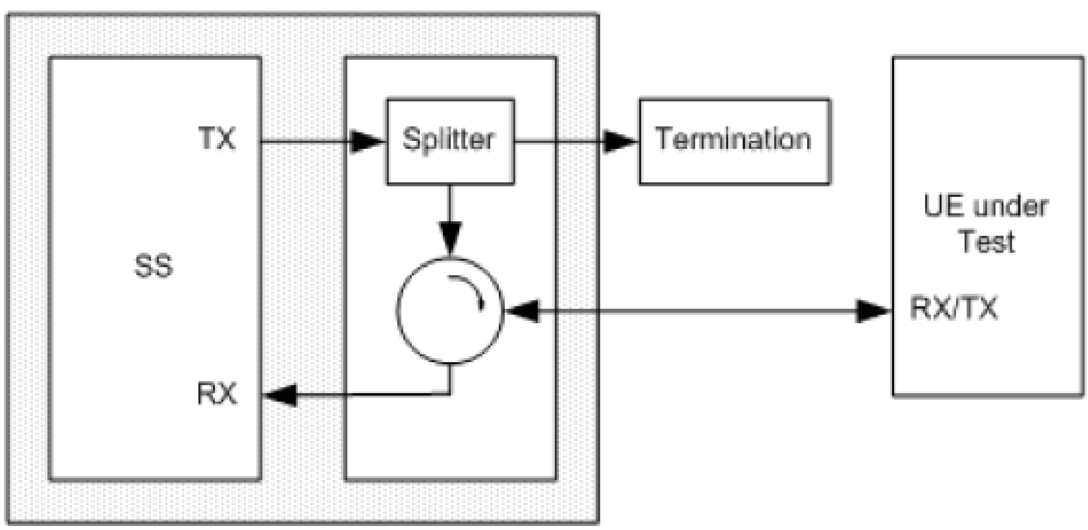


Figure 7. Adding a termination to one of the signals and testing SISO, 1x1

99. These configurations are used for all the test cases required by Verizon for all their vendors. However, it is known that vendors may improve and supplement set up requirements specified in the current diagrams with their own.

100. Verizon describes the Verizon Emulators in the Verizon ODN Spec at MWVZ00000037 as follows:

Test Channels

All tests in this test plan shall be performed using the following channels only:
" Downlink channel number: 5230
" Uplink channel number: 23230

Connection Diagrams

2 Cells, Intra-Frequency, AWGN Only
3 Cells, Intra-Frequency, AWGN Only
2 Cells, Intra-Frequency, AWGN with Fading
3 Cells, Intra-Frequency, AWGN with Fading
Simultaneous Test Execution

To reduce test time, the test platform shall execute the following test cases simultaneously:
" 2.1 and 2.3
" 2.2 and 2.4

Common eNB Configuration Information
The test platform shall configure all eNB's as follows:
" Downlink 2x2 transmit diversity shall be used.
" RA/RB shall be -3 dB.

The default parameters for simulated cells shall be

Figure 8. Configurations of 2, 3 Cells with Noise and Fading.

verizon✓ Verizon Wireless LTE 3GPP Band 13 Supplementary RRM Conformance

:

o Cell 1 in the tests in this test plan shall be per "Cell 1" in Table 4.4.2-1A of 3GPP TS 36.508: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing.
o Cell 2 in the tests in this test plan shall be per "Cell 4" in Table 4.4.2-1A of 3GPP TS 36.508: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing.
o Cell 3 in the tests in this test plan shall be per "Cell 12" in Table 4.4.2-1A of 3GPP TS 36.508: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing.
o All cells shall be in the same tracking area.
" All cells shall be time synchronized.
" For test cases that require connected-mode DRX, the following parameters shall be used for connected-mode DRX:
o drxInactivityTimer = PSF200
o drxRetransmissionTimer = PSF2
o longDrxCycle = SF320
o onDurationTimer = PSF10

101. As shown in the capture below, the same document includes the following table as well with RSRP (Reference Signal Received Power - Signal strength) values including power levels (Signal Strength) for the various System Information Blocks (SIB1, SIB3, and SIB4).[13]

[13] MWVZ00000074-MWVZ00000075.

Noc Note2	dBm/15 kHz	-124.0		
Es/Iot RSRPNote3	dB dBm/15 kHz	4.21 -112.0	-5.26 -117.0	N/A N/A
RSRQNote3	dB	-12.19	-17.19	N/A
IoNote3 Es/Noc	dBm/9 MHz	-82.82 12.0	 7.0	 N/A
Propagation condition		AWGN, EPA5, EVA70		
Note 2: Interference from other cells and noise sources not specified in the test is assumed to be constant over subcarriers and time and shall be modelled as AWGN of appropriate power for *Noc* to be fulfilled. Note 3: RSRP, RSRQ, and Io levels have been derived from other parameters for information purposes. They are not settable parameters themselves. Note 4: RSRP and RSRQ minimum requirements are specified assuming independent interference and noise at each receiver antenna port.				

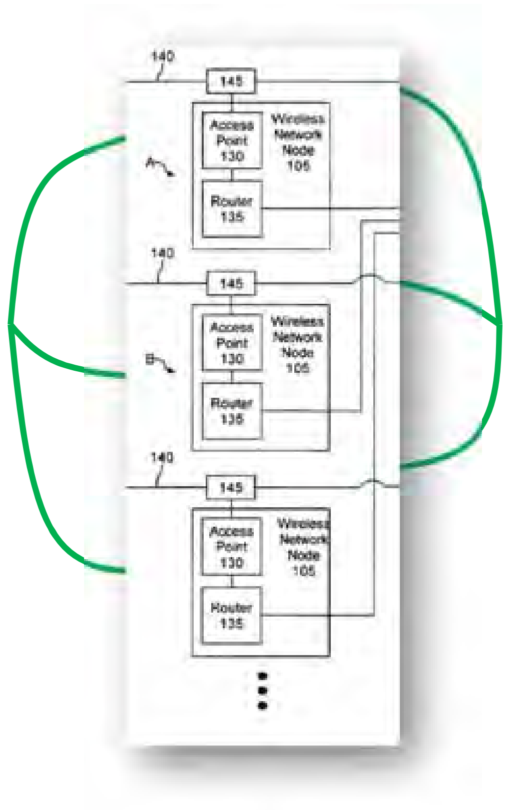
102. The System Information Blocks used are set to different attenuation levels: [14]

Table 2.4.26. Critical SIB reselection parameters for RSRQ intra-frequency accuracy tests.

Parameter	**Test 1**	**Test 2**	**Test 3**	**Test 4**
SIB1: q-RxLevMin q-RxLevMinOffset q-QualMin q-QualMinOffset	 -62 (-124 dBm) 6 (12 dB) -19 (-19 dB) Omitted	 -55 (-110 dBm) 8 (16 dB) -16 (-16 dB) Omitted	 -45 (-90 dBm) 8 (16 dB) -16 (-16 dB) Omitted	 -61 (-122 dBm) 8 (16 dB) -16 (-16 dB) Omitted
SIB3: q-Hyst q-RxLevMin s-IntraSearch s-IntraSearchP s-IntraSearchQ q-QualMin	 dB24 (24 dB) -62 (-124 dBm) 6 (12 dB) 6 (12 dB) 8 (8 dB) -19 (-19 dB)	 dB24 (24 dB) -55 (-110 dBm) 9 (18 dB) 9 (18 dB) 8 (8 dB) -21 (-21 dB)	 dB24 (24 dB) -45 (-90 dBm) 9 (18 dB) 9 (18 dB) 8 (8 dB) -16 (-16 dB)	 dB24 (24 dB) -61 (-122 dBm) 9 (18 dB) 9 (18 dB) 8 (8 dB) -16 (-16 dB)
SIB4: q-OffsetCell	 dB0 (0 dB)	 dB0 (0 dB)	 dB0 (0 dB)	 dB0 (0 dB)

[14] MWVZ0000074-MWVZ00000075.

103. For example, in the '330 Patent the attenuators are directly linked to the base stations linked to the phones under test just as disclosed in Figure 1 of the '330 Patent, excerpted below with my annotations:



104. Each cell, or SS1, SS2, SS3 are the Foreign Agents or a Wireless Network Nodes described in the patent. The SS1, SS2, SS3 implemented by Spirent and ROHDE Schwarz, ANITE, and other vendors as presented the document called: "LTE_3GPP_Band_13_Test_Equipment_List_June2013" (MWVZ0000001-00000036).

105. For example, ROHDE & Schwarz equipment uses TS8980FTA / TS-RR to implement the system simulator and loads the following conformance software.[15]

[15] VZW – abbreviation for Verizon, and the test name of the file used and referenced within Verizon ODN Spec (MWVZ00000001-00002179).

a. Test Pack for **VZW FDD13 supplementary RF conformance** (TS8-KM920/921)

b. Test Pack for **VZW FDD13 SVLTE supplementary RF conformance** (sections 2.1.1 and 2.1.2) - (TS8-KM925)

c. Test Pack for **VZW LTE 3GPP Band 13 Supplementary RRM Conformance**

Figure 9 TS8980FTA by ROHDE & SCHWARZ

Figure 10. CMW500 Protocol Tester by ROHDE & SCHWARZ

SPIRENT					
PLATFORM ID	SPI1	PLATFORM ID	SPI2	PLATFORM ID	SPI3
Platform Vendor	Spirent	Platform Vendor	Spirent	Platform Vendor	Spirent
Platform Name	8100-8200 (Data/Mobility)	Platform Name	8100-8100 (RF)	Platform Name	8100-8500 (LTS)
HARDWARE		HARDWARE		HARDWARE	
Make	Model	Make	Model	Make	Model
Spirent	E20105 (Single Cell is default; Dual Cell unit required for Stress Testing)	Spirent	E30105	Spirent	E20105 (Single Cell is default; Upto 3-LTE cell config required for E911 test plan)
Spirent	X202 (Optional) : Needed for Carrier Agg BT				
Spirent	SR3920	Spirent	SR8048	Spirent	SR8068
Spirent	SR8078	Agilent	N9010A-503	Spirent	GSS6700
Spirent	SR3452 (x2) (Optional): *Needed for InterRAT, Stress & SVLTE Data*	Agilent	E4438C (x2)	Spirent	SR3452 (x1) (Optional): Needed for Multimode SUPL2.0 and E911 testing. NOT needed for LTE-only SUPL2.0 testing
Spirent	SR3462 *(Optional): Needed for InterRAT, Stress & SVLTE Data*	Agilent	*8960 (Optional): Needed for SVLTE LTE RF & SVLTE 1x RF*	Spirent	SR3462 (x1): Needed for Multimode SUPL2.0 testing. NOT needed for LTE-only SUPL2.0 or E911 testing.
Spirent	SR5500M *(Optional): Needed for Stress and ACM testing*	**Note:** *Please look at SPI3 platform definition for SVLTE 1x RF coverage*		Spirent	RF Inter-connect Panel: Needed test cases with 2 and 3 LTE cells
Spirent	WTS122 *(Optional) : Needed for VoWifi*				
Spirent	SR5725 *(Optional): Needed for RCS ePDG wifi offload testing*				
Software		Software		Software	
Name	Version	Name	Version	Name	Version
Test Manager	2.8.376	Test Manager	2.8.346	CS8 IT	4.12.001
CS8 IT	4.12.002	CS8 IT	1.60.016	Testdrive LTS	10.00.105
AirAccess	4.81.002			PosAPP (SimGen)	5.06.001
Data Client	1.16.250 or above	AirAccess	4.50.007	AirAccess	4.81.002
Spirent IMS Client	3.3.0021	TAKSKIT C2K	7.20		
		Data Client	1.14.232		
Script /Test Pack	Script /Test Ver.	Script /Test Pack	Script /Test Ver.	Script /Test Pack	Script /Test Ver.
LTE Mobility Test Packs 1 & 2	14.0.20.0	LTE RF Performance Test Pack	1.6		
				VZW SUPL2.0 Test Pack	3.0.1

Figure 11. Spirent Test Equipment used by Verizon

ROHDE & SCHWARZ

PLATFORM ID	ROH1
Platform Vendor	Rohde & Schwarz
Platform Name	TS8980FTA / TS-RRM
HARDWARE	
Make	Model
Rohde & Schwarz	TS8980FTA / TS-RRM
Software	
Name	Version
CONTEST	≥BASE-15.10.1
Script /Test Pack	Script /Test Ver
Test Pack for VZW FDD13 supplementary RF conformance (TS8-KM920/921)	RF-LTE 3.90, (3.90.1 Signalling Adapter), RF-LTE 3.91 and RF-LTE 4.01
Test Pack for VZW FDD13 SVLTE supplementary RF conformance (sections 2.1.1 and 2.1.2) - (TS8-KM925)	RF-LTE 3.90, (3.90.1 Signalling Adapter), RF-LTE 3.91
Test Pack for VZW LTE 3GPP Band 13 Supplementary RRM Conformance	RRM 7.10

PLATFORM ID	ROH2
Platform Vendor	Rohde & Schwarz
Platform Name	CMW500 Protocol Tester
HARDWARE	
Make	Model
Rohde & Schwarz	CMW 500
Software	
Name	Version
CMW Base	>=3.5.80
CMW Data Application Unit	>=3.5.31
CMW Protocol Test Support	>=3.5.11
CONTEST**	≥BASE-15.11 (only ver with ** below need
Script /Test Pack	Script /Test Ver
Test Pack for VZW data retry KF570	30.32.2
Test Pack for VZW Suppl Signaling KF577	50.32.2
Test Pack for VZW InterRAT Performance KF576	50.21.4
Test Pack for VZW COMPLIANCE TEST PLAN LTE-RICH COMMUNICATION SERVICES DEVICES KAF74	5.50**
Test Pack for VZW InterRAT SVD KF579	29.29.1
Test Pack for VZW IMS Registration and Retry KAF75	5.50**

PLATFORM ID	ROH3
Platform Vendor	Rohde & Schwarz
Platform Name	CMW500 Protocol Tester - Throughput
HARDWARE	
Make	Model
Rohde & Schwarz	CMW 500
Rohde & Schwarz	AMU200A
Rohde & Schwarz	TS8980PC1Control PC
Rohde & Schwarz	VTF
Software	
Name	Version
CONTEST	≥BASE-14.00
DAU Version	
Media Version	
Script /Test Pack	Script /Test Ver
Test Pack for VZW FDD13 data throughput (TS8-KM922/927)	PQA 3.70
Test Pack for VZW FDD13 SVLTE LTE Data w/1x Voice conformance (sections 2.1.3 and 2.2.2) - (TS8-KM926)	PQA 3.70

106. Other vendors listed and approved by Verizon's LTE Platforms and test labs are:

a. ANITE (ANI)

b. ANRITSU (ANR1)

c. ROHDE & SACHWARZ (ROH2, ROH3, ROH7, ROH8)

d. CETECOM

e. COMPRION

f. SETCOM

g. SGS

h. SPIRENT (SPI2)

i. W2BI (W2BI15, W2BI6)

j. WITS

k. 7 Layers (7LA1)

LTE Platform List		
Test Plan	**VZW Approved Platforms**	**Platforms in Development**
Verizon Wireless LTE Supplementary Signaling Conformance Test Plan	**ANI1,ANR1,ROH2,W2B15,W2B16**	**W2B20**
Verizon Wireless LTE 3GPP Band 13 Supplementary RF Conformance Test Plan	**ANR2,ROH1,SPI2**	
Verizon Wireless LTE Data Retry Test Plan	**ANI1,ANR1,ROH2,SPI1, W2B15,W2B16**	**W2B20**
Verizon Wireless LTE 3GPP Band 13 Data Throughput Test Plan	**ANI2,ANR1,ROH3,SPI1**	**W2B15**
Verizon Wireless LTE SMS Test Plan	**ANI1,ANR1,ROH2,SET1, W2B7,W2B8**	**W2B20**
Verizon Wireless LTE Device-UICC (USIM, ISIM) Interaction	**COM1,7LA1**	
LTE AT Commands for Test Automation Test Plan	**W2B7,W2B8,ANI1,WIT1, SGS1,CET1**	**W2B20**
IMS Registration and Retry	**ANI1,SET1,W2B7,W2B8, ROH2**	
LTE Over the Air Radiated Performance Test Plan	**ROH7 & ROH8**	

107. Additionally, in the document "23JUN2016 Open Access Test_Equipment_List _OD" other vendors are listed with similar test equipment including a new vendor: AGILENT / KEYSIGHT.

108. The list of vendors and approved platform presented in that document is summarized in the following chart:[16]

[16] MWVZ00001417.

LTE Platform List				
Test Plan	**VZW Approved Platforms**			**Comments**
LTE B13 supplementary signaling Conformance	ANI1	ANR1	ROH2	
	W2B15	W2B16		
LTE B13 Supplementary RF Conformance	ANR2	ROH1	KEY1	
	ROH9			
LTE B13 Supplemental RRM	ANR2	ROH1	ROH9	
LTE 13 Data Retry	ANI1	ANR1	ROH2	
	W2B15	W2B16		
LTE B13 Data Throughput	ANR1	ROH3		
	SPI1	ANI1		
LTE SMS	ANI1	ANR1	ROH2	
	SCO1	W2B7	W2B8	
Device-UICC_USIM-ISIM. Section 2: electrical (Test cases 1-6)	COM1			
Device-UICC_USIM-ISIM Section 2: protocol (Testcases 7-20)	COM1	COM4	7LAY1	
Device-UICC_USIM-ISIM- Sections 3, 4 &5	COM1	COM4	7LAY1	
	W2B7			
Device-UICC_USIM-ISIM- Sections 6	W2B7			
AT Command	W2B7	W2B8	ANI1	
	WIT1			
LTE IMS Registration and Retry	ANI1	SCO1	W2B7	
	W2B8	ROH2	ANR1	

Figure 12. LTE Platform Lists used for Simulation and Emulation.

109. For instance, ANRITSU ME7384L is presented in "LTE 3GPP Band13 Supplementary RF Conformance Test Plan_October 2017," a vendor's picture is presented herein:

Figure 13. ANRITSU ME7384L

110. In short, the components in Element 1 of the Claim show infringement of this Element 1. This infringement is literal infringement.

a. A plurality of wireless network nodes with 2 to 3 network nodes at a particular location; and

b. Configured to change wireless communications characteristics (e.g. Attenuation, AWGN).

111. The Court's Markman Order requires that the wireless network nodes send and receive signals wirelessly (over the air) without wires.

112. However, using a conductive test is equivalent to a wireless test as both achieve the same end goal of controlling attenuation, and Signal to Noise Ratio. [17]

<u>NOTE 2:</u> All transmitter signal quality and transmitter emissions requirements defined by 3GPP in 3GPP TS 36.101: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception*) that are **<u>relative measurements</u>** (e.g. carrier leakage, in-band emissions, adjacent channel leakage ratio, etc.) shall be met both conducted (at the UE antenna ports) **<u>and radiated</u>**.

113. Further, Verizon does radiated tests. Radiated means without wires or cables, and conductive is taking the wireless signal as close as possible to the phone's antenna or antenna(s). In radiated tests, the last portion of connectivity is wireless in nature thus satisfying the court definition of wireless network node.[18]

16 3.2 REFERENCE SENSITIVITY SINGLE RECEIVER (QPSK)

VZ_TC_SUPRFCONF_1635

Definition

This test verifies that the UE meets Verizon Wireless requirements for UE receiver reference sensitivity with single receiver operation. This test is required to support radiated performance testing as per the Verizon Wireless LTE Over-the-Air Radiated Performance Test Plan.

Traceability

- Verizon Wireless LTE 3GPP Band 13 Network Access Device Requirements, Section *Verizon Wireless-Specific LTE 3GPP Band 13 RF Performance Requirements*
- 3GPP TS 36.101: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception*, section 7.3
- 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*, section 7.3

Applicability

This test case applies to all UEs designed to operate on the Verizon Wireless LTE 3GPP Band 13 network.

114. I interpret the Court's definition of "wireless" to mean that the communication path that is "wireless" must be without wires and through air, and not to mean that there can be absolutely no wires or circuits anywhere in the accused system.

115. Therefore, Verizon clarifies to their vendors the following statement[19]:

[17] MWVZ00002050.
[18] MWVZ00000139.
[19] MWVZ00000315.

5.6 Over-the-Air Performance Simulation

Where indicated in section 3.12 of this test plan, the test platforms fader shall simulate the impact of the UEs antenna by incorporating the complex antenna pattern data for the UE. The test platform shall be capable of accepting UE complex antenna pattern data in the format specified in section 6.16.4.1 of the CTIA Test Plan for Mobile Station Over the Air Performance, Revision 3.1.

Device vendors shall provide complex antenna pattern data in the format specified in section 6.16.4.1 of the CTIA Test Plan for Mobile Station Over the Air Performance, Revision 3.1 (LTE radiated performance testing is per the Verizon Wireless LTE Over-the-Air Radiated Performance Test Plan).

116. This clearly means that emulated over-the-air propagation is taking place in accordance to the UE antenna pattern data.

117. MIMO antennas which the system is designed to have, require OTA (Over the Air) testing as complex antenna patterns cannot be tested otherwise.[20]

118. Additionally, in all cases where a reverberation chamber, or anechoic chamber is used, "wireless, or without wires" is implemented literally or under doctrine of equivalence.

119. The CTIA Test Plan of Mobile Station Revision 3.1, Section 3.12 presents the antenna patterns that can be emulated or simulated to recreate a virtual radiated test, that mimics Over-the-Air systems:[21]

[20] https://www.microwavejournal.com/ext/resources/pdf-downloads/chapter1-Spirent.pdf.

[21] MWVZ000002872 – CTIA "Test Plan for Mobile Station Over the Air Performance" Rev 3.1, January 2011.

6.16.4 RSS Data Format

This section specifies the format for EUT-generated RSS data used in the TIS pattern measurement process and other RSS-based tests under development. The EUT shall generate data in the specified format, either directly or via an intermediate data parser.

6.16.4.1 RSS Data Stored Locally on EUT

RSS data stored locally on the EUT during the pattern measurement process shall take the form of a comma-delimited ASCII text file. Each row or line of the file shall contain a single time stamped RSS measurement record. Each record shall terminate with a Carriage Return (decimal ASCII code 13) or Carriage Return/Line Feed combination (decimal ASCII codes 13+10).

Each measurement record or file line shall contain 6 fields as specified below separated by commas:

- **Date:** YYYY-MM-DD (e.g. "2008-03-15")
- **Time:** HH:MM:SS.000 (e.g. "16:20:01.568"). 24-hour format. The number of decimal points for fractional seconds shall depend on the available time resolution of the EUT's underlying technology.
- **Signal Source:** Integer index indicating the signal source for air interfaces using multiple signal sources, e.g., multiple-satellite GPS scenarios. In cases where signal sources have standard numerical identifiers, such as GPS satellite IDs, this field shall contain that identifier. Otherwise, this field shall index starting from 0.
- **Antenna:** Integer index, starting from 0, indicating the antenna or receive chain for EUTs supporting multiple receivers. This value shall always be "0" for single-antenna devices.
- **RSS:** Received Signal Strength value (power in dBm; ratios in dB).
- **Phase:** Phase angle of received signal in radians. This value shall always be "0" if no phase information is provided.

The date and time fields must represent accurate elapsed time over the data collection period, but they are not required to be synchronized to a specific time-of-day reference. However, if these time stamps are not explicitly synchronized to the time reference used by the range equipment, the test solution developer must provide a mechanism to account for the time offset between EUT data and any range-specific data (e.g. position) collected simultaneously.

Figure 6-1 shows an example data segment for a single-antenna device generating no phase information, with a single signal source. Figure 6-2 shows an example data segment for a dual-antenna device generating phase information, with a single signal source.

FIGURE 6-1 EXAMPLE RSS DATA SEGMENT FOR A SINGLE-ANTENNA DEVICE PROVIDING NO PHASE INFORMATION, WITH ONE SIGNAL SOURCE

```
2008-03-15,16:20:01.568,0,0,-83.22,0
2008-03-15,16:20:01.771,0,0,-83.17,0
2008-03-15,16:20:01.964,0,0,-82.89,0
2008-03-15,16:20:02.167,0,0,-82.83,0
2008-03-15,16:20:02.362,0,0,-82.97,0
```

120. It is clear that Verizon's lab and all test plans require a plurality of base stations or wireless network nodes that communicate with the baseline phones that manufacturers are creating for Verizon. Verizon does OTA testing and loads antenna patterns for Virtual OTA Testing.

121. By following the paths of TX1 and TX2 signals into the "Device Under Test," we can conclude that the following happens to TX1 and TX2 where the variable names represent the observed signal strength in the respective lines:

$$DUT - RX = \sum (TX1 * Fader_i + TX2 * Fader_i) + AWGN$$

122. Where $Fader_i$ represents the path for each fader and will reflect on certain amount of attenuation as shown in the Figure below:

123. A similar equation is found when we see the signals from all antennas and by the superposition principle, we know that when signals transmitted over the air they are all combined as follows:

$$DUT - \ RX = \sum (TX1 * Fader_i + TX2 * Fader_i) + AWGN$$

124. The main difference between the Verizon's emulator and the '330 patent resides in the SS1, SS2, and SS3, RX path, as shown in the figure RX=TX whereas in the patent

$$SS_iRX = DUT_{TX} \ \ where\ i\ is\ 1\ to\ 3$$

125. And the '330 patent

$$SS_iRX = \sum (DUT_{TX} * Fader_i) + AWGN \quad where\ i\ is\ \ 1\ to\ 3$$

126. Which means that, Verizon did not consider the "Reverse path" as important for their simulation, and simply DUT's transmitted signal suffers no attenuation while traveling to the tower, which is unrealistic.

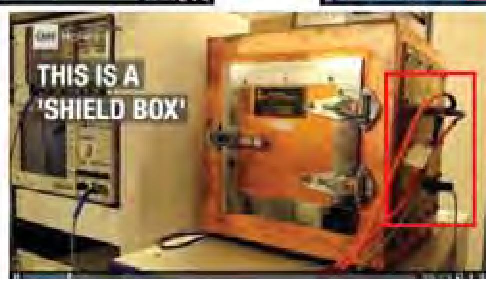
127. This may or may not be followed by vendors as SPIRENT appears to process both paths equally.

128. Within the Infringement Contentions the following diagram was presented using Verizon's video as a source:

‘330 Patent – Claim 1 – Element (A) 12

a plurality of fixedly-located wireless network nodes configured to variably adjust wireless communication characteristics;

- Defendant's Accused Product includes a plurality of fixedly-located wireless network nodes configured to variably adjust wireless communication characteristics.
  - For example, Defendant's Accused Product includes a system with multiple antennae (i.e., inside an anachoic chamber) configured to variably adjust wireless communication characteristics.



Further,

- Defendant's Accused Product includes at least one mobile node configured to wirelessly communicate with selected ones of said plurality of wireless network nodes.
  - For example, Defendant's Accused Product includes a system where one mobile node (e.g, a cellular phone) is configured to wirelessly communicate with the selected base stations.

Source: http://money.cnn.com/video/technology/2016/02/22/verizon-device-testing.cnnmoney/

129. In general testing can be performed within a Faraday cage, anechoic chamber, or within an RF shield box. As shown in Figure 14, Spirent and similar vendors will show the same setup.

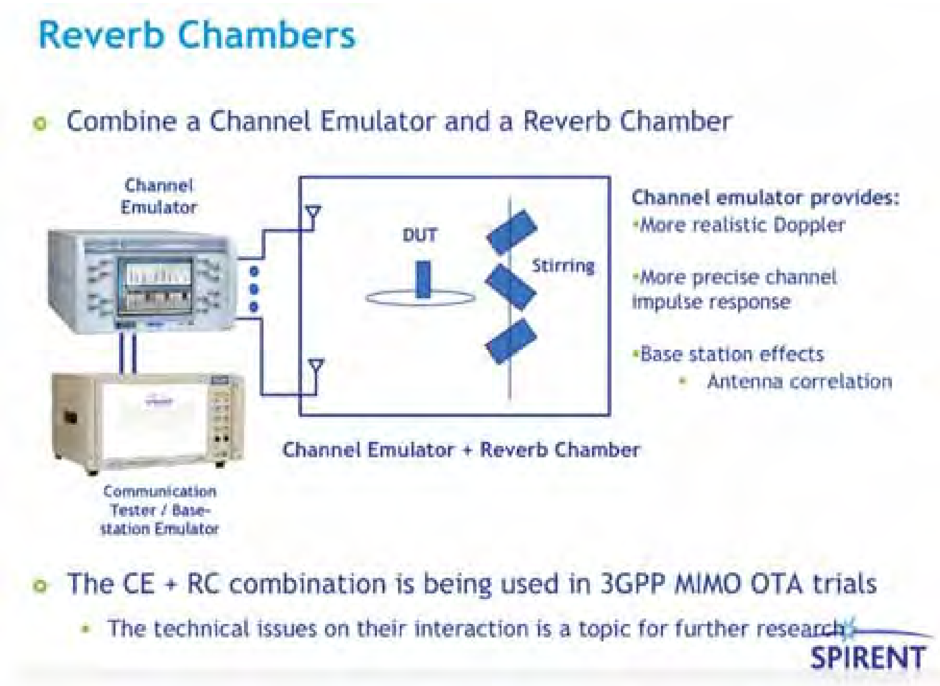


Figure 14. Device under Test - MIMO and Channel Emulator

2. Element 2 Discussion

130. The second element refers to the "Device Under Test" or "User Equipment" (UE), which satisfies "At least one mobile phone" configured to wirelessly communicate with wireless network nodes.

131. We know that device under test, could use SISO or MIMO Antennas. When MIMO is in use, OTA or over-the-air is the most effective way to test a phone. Verizon's OTA requirements already specify how this is done.

Element 2 of claim 1: at least one mobile node configured to wirelessly communicate with selected ones of said plurality of wireless network nodes;	Verizon refer to mobile devices and radios used to test the plurality of cells (at least 2 or 3 Cells from the Requirements documents)[22] Thus, Element 2 of claim 1 is satisfied.

[22] MWVZ00000037.

132. Therefore, Verizon literally infringes Element 2 of claim 1, as the “Device Under Test” relates to a Mobile Phone, an IOT device, a tablet, even a smart watch that uses an LTE SIM card.

133. The Device Under Test (“DUT”) are required to support specific “AT Commands” and are configured to work in compliance with FCC Rules for 700 MHz band, to enable certain test modes as follows:[23]

Introduction

Verizon Wireless requires all devices designed to operate on the Verizon Wireless LTE 3GPP Band 13 network to support AT Commands as detailed in the Verizon Wireless LTE AT Commands For Test Automation Requirements. This document describes the test procedures and the minimum test "pass/fail" criteria to ensure each required command has been implemented correctly.

This publication is part of Verizon Wireless compliance with the FCCs rules for 700 MHz C Block (47 C.F.R. § 27.16), as explained in the FCCs Second Report and Order in WT

Verizon Wireless LTE AT Commands for Test Automation

Docket No. 06-150, "Service Rules for the 698-746, 747-762 and 777-792 MHz Bands" released on August 10, 2007.

In this document, the terms LTE (Long Term Evolution) and E-UTRA (Evolved Universal Terrestrial Radio Access) are considered equivalent.

Test Objectives

The objective of this document is to define the Verizon Wireless LTE AT Command testing procedures for lab-based testing of devices designed to operate on the Verizon Wireless LTE 3GPP Band 13 network.

This document will be used by employees of device manufacturers, test labs, and Verizon Wireless to guide the execution of Verizon Wireless LTE AT Command functionality testing.

134. Hence, the devices under test (DUT) are configured to wirelessly communicate with the wireless network nodes, and Element 2 is met.

3. Element 3 Discussion

[23] MWVZ00000193.

Element 3 of claim 1: a network emulator communicatively linked to each of said plurality of wireless network nodes, said network emulator configured to emulate attributes of a packet-based wired communications network for simulating network conditions experienced by said at least one mobile node in communicating with other nodes through the wired communications network, the emulated attributes comprising at least one of tunable packet-delay distribution, network congestion, bandwidth limitation, and packet re-ordering and duplication; and	Verizon calls them “Test Equipment”, “Network Simulator” and others, to simulate packet data scenarios such as setting up a Mobile IP Address, UDP Packet Throughput, TCP/FTP Throughput, IMS Test plan with VoIP calls among many others. Thus, this element 3 is satisfied.

135. Verizon and vendors use the term “Network Emulator” and how it connects to the SS1, SS2, SS3, as “System Simulator” or “Test Equipment”.

136. In the document on pg. 21 states that “LTE Band 13 Data Throughput _Test_Plan_February2018.”[24]

- UE Capability Transfer
- RRC Connection Reconfiguration
- The network emulator shall assign both an IPv4 and an IPv6 address for the internet PDN on attach.

137. In the document called “LTE 3GPP Band13 Supplementary RF Conformance Test Plan_October 2017” on pg. 24 states:[25]

[24] MWVZ0000319.
[25] MWVZ0000109.

\

> 1. *conformance specification; Radio transmission and reception; Part 1: conformance testing*. The network emulator shall signal NS_07 to the UE using the message contents as per section 6.6.3.3.4.3.2 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*.

138. In the document, "LTE Data Retry IMS Less Test Plan_Feb2019" on pg. 16 states that:[26]

Pre-Conditions (Step 1)

Procedures (Step 1)

Test Procedure

1. Configure the test equipment to respond to all RRCConnectionRequest messages with an RRCConnectionReject message. Configure the test equipment such that the value for waitTime in the RRCConnectionReject message is 10 seconds.
2. Verify that the device under test (DUT) has an Internet application that will attempt to connect to the Internet PDN as soon as the DUT is powered on and finds service on the LTE network.
3. Power the DUT on and allow it to find LTE service.
4. Verify that the DUT attempts to attach to the LTE network and that the network responds to the RRCConnectionRequest message with an RRCConnectionReject message with a waitTime value of 10 seconds.
5. Verify that after 10 seconds, the DUT attempts to attach to the LTE network a second time and that the network responds to the RRCConnectionRequest message with an RRCConnectionReject message with a waitTime value of 10 seconds.
6. Re-configure the LTE network emulator to allow the RRC connection setup to succeed.

139. In the document "LTE_Supplementary_Signaling_Conformance_TestPlan_Feb2019" on pg. 80.[27]

[26] MWVZ00000632.
[27] MWVZ00001748.

4	TE emulator sends disconnects RRC connection and transition the UE to RRC Idle mode.	<=	RRCConnectionRelease	N/A
5	Configure the network emulator to ignore the next two random access preambles from the device. On the 3rd access preamble, indicates contention resolution not successful in MSG4 by setting a different Contention Resolution ID (not matching the CCCH SDU transmitted in Msg3). On the 4th access preamble, allow random access to be successful.	-	-	-

140. Besides many other references, Verizon's document "23JUN2016 Open Access Test_Equipment_List _OD" uses the word "Network Emulator Software."[28]

	Rev - same as E6621A
Agilent Technologies	E6966A option 1FP IMS-SIP Network Emulator Software Rev 03.00.00 or later
Script /Test Pack	**Script /Test Ver**

Element 3 of claim 1: a network emulator communicatively linked to each of said plurality of wireless network nodes, said network emulator configured to emulate attributes of a packet-based wired communications network for simulating network conditions experienced by said at least	Verizon calls them "Test Equipment", "Network Simulator" and others, to simulate packet data scenarios such as setting up a Mobile IP Address, UDP Packet Throughput, TCP/FTP Throughput, IMS Test plan with VoIP calls among many others. Thus, this element 3 is satisfied.

[28] MWVZ00000003.

one mobile node in communicating with other nodes through the wired communications network, the emulated attributes comprising at least one of tunable packet-delay distribution, network congestion, bandwidth limitation, and packet re-ordering and duplication; and	

141. Verizon simulates bandwidth, network congestion, and packet delays. For example, in "LTE Band 13 Data Throughput _Test_Plan_February2018."[29]

5.19 Embedded Operation

For smartphone and tablet devices, the test platform shall support embedded operation, i.e. the test platform shall include a data client test application that is installed on the device for data throughput measurements. This embedded data client test application shall meet the minimum requirements specified in Annex E of 3GPP TR 37.901: *User Equipment (UE) application layer data throughput performance*. Refer to section 1.6 for the test cases that require embedded operation. The embedded data client test application shall support FTP, UDP, IPv4, IPv6, test type (i.e. downlink, uplink, bidirectional), and the minimum file sizes specified in this document for the test cases that require embedded operation. The embedded data client test application shall also support ping packets to test proper MTU size enforcement by the modem. The embedded data client test application shall support different ping packet sizes and the setting of the packet "Do Not Fragment" bit refer to test case 2.4 for additional details.

142. In a similar fashion, Round-Trip Delays are measured using the emulator as follows:[30]

[29] MWVZ00000320.
[30] MWVZ00000333.

Test 1

1. Power on the UE and connect the UE to the network emulator.
2. Configure the network simulator for single cell signaling conformance testing per 3GPP TS 36.508: *Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing.* The network emulator shall verify that the UE attaches to the network.
3. The network emulator shall then release the RRC connection to the UE, causing the UE to transition to the RRC_IDLE state, i.e. EMM-REGISTERED and EMM-IDLE.
4. The test platform shall command the UE to initiate an RRC connection, i.e. the UE sends the *RRCConnectionRequest* message to the network emulator.
5. After the UE sends the *RRCConnectionReconfigurationComplete* message, the test platform shall command the UE to start sending 32 byte pings to the PDN gateway.
6. Upon receipt, the PDN gateway shall send the pings back to the UE.
7. Measure/Record the total round trip delay (at the IP layer) of each ping.

143. Another Packet-based Communications feature is connecting to a router element or a layer-3 system for communications. As such, the UE sends router solicitation messages as presented in the LTE Supplementary Signaling Conformance IMS Less Test Plan_Feb2019 on pg. 16.[31]

[31] MWVZ00001186.

Pre-Conditions (Step 1)				
The network simulator is configured for signal conformance testing as described in Section ***Test Equipment Configuration*** and powered on. The device (UE) under test is then connected to the network simulator. After the UE is powered on, acquired and synchronized to the network, the following procedures should be either initiated by the UE or performed in response to messages received by the UE.				
Procedures (Step 1)				
Step	**Procedure**	**Message Sequence**		**Verdict**
		U - S	**Message**	
1	Configure the UE to perform the Initial Attach procedure to the LTE network	-	-	N/A
2	Ensure the Initial Attach procedure in Section 2.1 is completed			N/A
2a	Check: Confirm that the UE does not send out any Neighbor Solicitation messages during the initial Attach procedure.			Pass if no Neighbor Solicitation messages sent
2b	Check: Does the UE send out the Router	=>	Router Solicitations	Pass if message sent with the correct link-

Including simulation of distribution delays, as shown in the same document on pg. 16:

	message?			
3	Network simulator sends the router advertisement, with the "ValidLifetime" value set to 3 minutes, and the "RouterLifetime" value set to 5 minutes. Check: Examine the	<=	Router Advertisement	N/A

And,

	message?			
3	Network simulator sends the router advertisement, with the "ValidLifetime" value set to 3 minutes, and the "RouterLifetime" value set to 5 minutes. Check: Examine the	<=	Router Advertisement	N/A

144. In general, the document called LTE Data Retry Test_Plan_June2018" includes a set of test-cases that a packet-based communication network should emulate where delay values, bandwidth characteristics similar to real world environment and other packet-based communication characteristics are tested in multiple ways.[32]

Test Case		Embedded, Tethered, or Both *	IPv4, IPv6, or Both	UE Category	Applicable to Single Antenna M2M Devices
2.1	Average Network Attach Time (i.e. control plane latency)	Embedded	IPv6	>=1	Y
2.2	RRC_IDLE to RRC_CONNECTED Control Plane Latency Test 1	Embedded	IPv6	>=1	Y
	RRC_IDLE to RRC_CONNECTED Control Plane Latency Test 2	Embedded	IPv6	>=1	Y
2.3	User Plane Round Trip Delay Test 1	Embedded	IPv6	>=1	Y
	User Plane Round Trip Delay Test 2	Embedded	IPv6	>=1	Y
2.4	Internet PDN MTU Size Enforcement	Embedded	Both	>=1	Y

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Additionally, throughput which refers to Bandwidth is a parameter being emulated by the Verizon Emulator system:[33]

[32] MWVZ00000321.
[33] MWVZ00000322.

3.1	Downlink FTP Throughput Test 1	Embedded	IPv4	>=1	Y
	Downlink FTP Throughput Test 2	Embedded	IPv4	>=2	Y
	Downlink FTP Throughput Test 3	Embedded	IPv4	>=1	Y
	Downlink FTP Throughput Test 4	Embedded	IPv4	>=2	
	Downlink FTP Throughput Test 5 (VOID)	-	-	-	
	Downlink FTP Throughput Test 6 (VOID)	-	-	-	
	Downlink FTP Throughput Test 7	Embedded	IPv4	>=2	
	Downlink FTP Throughput Test 8	Embedded	IPv4	>=2	
	Downlink FTP Throughput Test 9	Embedded	IPv4	>=2	
	Downlink FTP Throughput Test 10	Embedded	IPv4	>=2	
	Downlink FTP Throughput Test 11	Embedded	IPv4	>=2	
	Downlink FTP Throughput Test 12	Embedded	IPv4	>=2	
3.2	Uplink FTP Throughput Test 1	Embedded	IPv4	>=2	Y
	Uplink FTP Throughput Test 2	Embedded	IPv4	>=1	Y
	Uplink FTP Throughput Test 3	Embedded	IPv4	>=1	Y
	Uplink FTP Throughput Test 4	Embedded	IPv4	>=1	Y
	Uplink FTP Throughput Test 5	Embedded	IPv4	>=1	Y
3.3	Bidirectional FTP throughput Test 1	Embedded	IPv4	>=2	
	Bidirectional FTP throughput Test 2	Embedded	IPv4	>=2	
	Bidirectional FTP throughput Test 3	Embedded	IPv4	>=1	Y

Many other test cases that include[34]:

	Bidirectional UDP throughput Test 3	Embedded	IPv6	>=1	Y
3.7.2	Simultaneous IPv4 and IPv6 UDP Data Transfers	Embedded	Both	>=2	
3.8	Stress Test FTP Throughput (Downlink) Test 1	Embedded	IPv4	>=2	
	Stress Test FTP Throughput (Downlink) Test 2	Embedded	IPv4	>=1	Y
3.9	Stress Test UDP Throughput (Bidirectional) Test 1	Embedded	IPv6	>=2	
	Stress Test UDP Throughput (Bidirectional) Test 2	Embedded	IPv6	>=1	Y
3.10	Downlink Power Sweep UDP Throughput	Embedded	IPv6	>=2	
3.11	Downlink UDP Throughput with Variable Reference Measurement Channels	Embedded	IPv6	>=2	
3.12	Downlink UDP Throughput with Advanced Channel Models	Embedded	IPv6	>=2	
	feICIC Downlink FTP Throughput in				

Additionally, "Data Throughout" is emulated using 3 simultaneous links for Cooperative Multi-Point test cases (CoMP):[35]

[34] MWVZ00000323.
[35] MWVZ00000324.

3.21	DL CoMP Data Throughput Tests with Three Transmission Points Test 1	Embedded	IPv4	>=2	Y
	DL CoMP Data Throughput Tests with Three Transmission Points Test 2	Embedded	IPv4	>=2	Y
	DL CoMP Data Throughput Tests with Three Transmission Points Test 3	Embedded	IPv4	>=2	Y
	DL CoMP Data Throughput Tests with Three Transmission Points Test 4	Embedded	IPv4	>=2	Y
	DL CoMP Data Throughput Tests with Three Transmission Points Test 5	Embedded	IPv6	>=1	Y
	DL CoMP Data Throughput Tests with Three Transmission Points Test 6	Embedded	IPv6	>=1	Y
	DL CoMP Data Throughput Tests with Three Transmission Points Test 7	Embedded	IPv6	>=1	Y
	DL CoMP Data Throughput Tests with Three Transmission Points Test 8	Embedded	IPv4	>=2	
	DL CoMP Data Throughput Tests with PDSCH in MBSFN Subframes Test 1	Embedded	IPv4	>=2	Y

145. As shown, the emulator uses terms as average, maximum, minimum, which clearly represent statistical parameter of probabilistic distributions.

146. Verizon integrates its "System Simulator" (or the Verizon Emulator) as shown in Figure 2 to Figure 4 in my Expert Report, clearly show a WiFi/Ethernet-based communication is taking place via a packet-based communications network which is emulated to reflect real world conditions. Also see Figure 15 below taken from the Verizon ODN Spec at MWVZ00000321:

** **NOTE:** The test cases apply when either UE Category or DL UE Category is 11 or above. Refer to the Release 12 version of 3GPP TS 36.306: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities*.

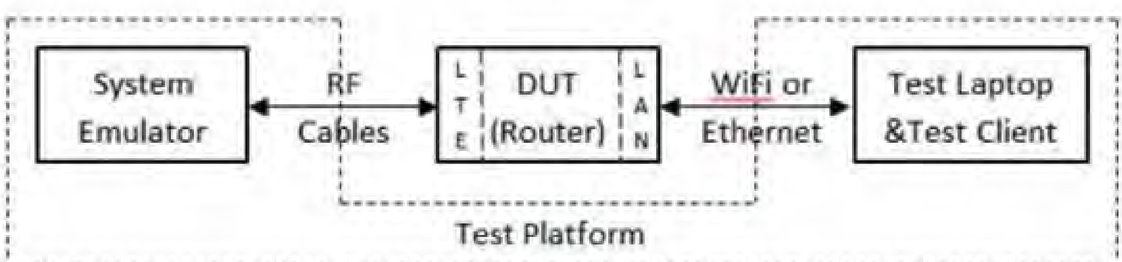

Figure 1.5.20: Test equipment configuration to support router

Figure 15. Controller used as a hotspot and DUT – Laptop used as a client

147. As show in the excerpts below, the Verizon ODN Spec as shown at MWVZ00000346 combine fading (propagation conditions), MIMO antennas, and bandwidth with the emulator for this particular test to function correctly.

> *conformance testing.*
>
> 2. Set the parameters of the bandwidth, MCS, reference channel, the propagation condition, the correlation matrix, antenna configuration and the SNR as specified for Test Number 1 in Table 8.2.1.2.1.5-1 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing* with the following exceptions:

> 2. Set the parameters of the bandwidth, MCS, reference channel, the propagation condition, the correlation matrix, antenna configuration and the SNR as specified for Test Number 1 in Table 8.2.1.2.1.5-1 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing* with the following exceptions:
>
>   1. MIMO correlation matrices shall be defined as in section ***MIMO CORRELATION MATRICES*** of this document.
>
> 3. Setup a FTP session to the test FTP server.

148. As shown in the following table, the System Emulator provides several scenarios for testing of bandwidth as follows, including data throughput as emulated by Verizon's system, in this table shows minimum average throughput, which represent statistical distributions throughput[36]. Following Table shows FTP downlink criteria acceptable for a UE.

[36] MWVZ00000317.

Criteria for FTP downlink throughput.

Test	Minimum Average Throughput (Mbps), Category 1 Device		Minimum Average Throughput (Mbps), Category 2 Device		Minimum Average Throughput (Mbps), Category 3+ Device	
	IPv4	IPv6	IPv4	IPv6	IPv4	IPv6
Test 1	50 Kbps	N/A	50 Kbps	N/A	50 Kbps	N/A
Test 2	-	-	8.0 Mbps	N/A	8.0 Mbps	N/A
Test 3	2.7 Mbps	N/A	2.7 Mbps	N/A	2.7 Mbps	N/A
Test 4	-	-	16 Mbps	N/A	16 Mbps	N/A
Test 5	VOID	VOID	VOID	VOID	VOID	VOID
Test 6	VOID	VOID	VOID	VOID	VOID	VOID
Test 7	-	-	16 Mbps	N/A	16 Mbps	N/A
Test 8	-	-	16 Mbps	N/A	16 Mbps	N/A
Test 9	-	-	31.9 Mbps	N/A	35.6 Mbps	N/A
Test 10	-	-	0.5 Mbps	N/A	0.5 Mbps	N/A
Test 11						
Test 12						

5.13 Data Throughput Calculation

For LTE data throughput testing, the data throughput for each test case shall be calculated as follows:

1. The time needed to transfer/stream a file for a given iteration is measured.
2. Based on the time measured in A.) and the file size, the average throughput for the iteration is calculated.
3. The average throughput values for all iterations are averaged to determine the final throughput value which needs to meet the pass/fail criteria.

The test platform shall report the FTP and UDP layer throughput results with the TCP/UDP headers removed. Pass/fail criteria shall be applied to the FTP/UDP layer throughput measurements with the TCP/UDP headers removed. The test platform shall also report throughput results at the SDU PDCP layer with the TCP/UDP headers included for informational purposes.

For LTE data throughput tests, a throughput iteration shall be invalid if the LTE data call drops during the iteration. If the LTE data call drops during a throughput iteration, the iteration shall be repeated. If the LTE data call drops again in the repeated iteration or in two iterations of the same test, then the entire test shall be failed.

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149. In conclusion, Verizon system uses the combination of RF wireless characteristics, and Packet-based communication systems (e.g. UDP Throughput) to test and evaluate a UE's performance as described in "LTE Band 13 Data Throughput _Test_Plan_February2018" pg. 107 (MWVZ0000040**5**).

5. Record the average throughput at the UDP layer on the downlink channel during the file transfer.
6. Repeat steps 4.) and 5.) for a total of 3 iterations.
7. End the UDP session.
8. The network emulator shall release the RRC connection to the UE.
9. Average all iterations.
10. Repeat steps 1.) through 9.) with the downlink channel power set to -56 dBm.
11. Repeat steps 1.) through 9.) with the downlink channel power set to -58 dBm.
12. Repeat steps 1.) through 9.) with the downlink channel power set to -60 dBm.
13. Repeat steps 1.) through 9.) with the downlink channel power set to -62 dBm.
14. Repeat steps 1.) through 9.) with the downlink channel power set to -64 dBm.
15. Repeat steps 1.) through 9.) with the downlink channel power set to -66 dBm.
16. Repeat steps 1.) through 9.) with the downlink channel power set to -68 dBm.
17. Repeat steps 1.) through 9.) with the downlink channel power set to -70 dBm.
18. Repeat steps 1.) through 9.) with the downlink channel power set to -72 dBm.
19. Repeat steps 1.) through 9.) with the downlink channel power set to -74 dBm.
20. Repeat steps 1.) through 9.) with the downlink channel power set to -76 dBm.
21. Repeat steps 1.) through 9.) with the downlink channel power set to -78 dBm.
22. Repeat steps 1.) through 9.) with the downlink channel power set to -80 dBm.

Figure 16. Signal Strength Modifications done by the network Emulator.

4. Element 4 Discussion

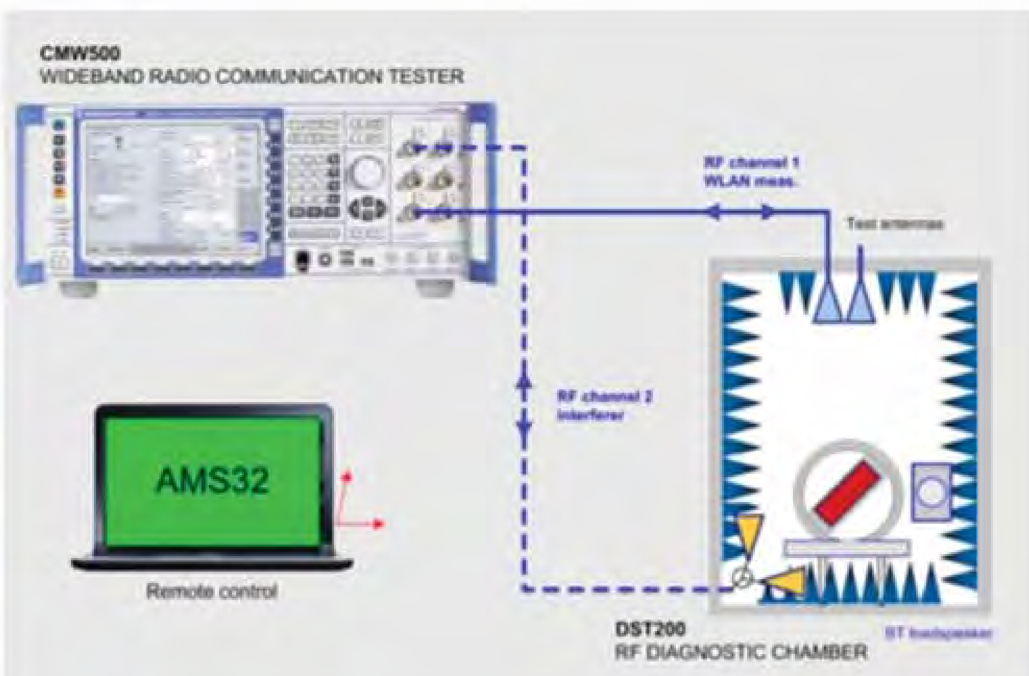
150. The last element of Claim 1 is a controller that is configured to change the parameters and automate the process of emulation. The controller remotely sets the values of SNR, Attenuation, and others, depending on the test harness in use. To that end the controller is configured to communicate with the wireless network nodes and change wireless communication characteristics, but it does not interfere with the mobile phone's behavior (e.g. Encoded in RF Shield Box) during testing.

Element 4 of claim 1: a controller communicatively linked to each of said plurality of wireless network nodes, said controller configured to control the wireless communication characteristics	A controller is required to automate testing by a script or a tool to control wireless communications characteristics such as attenuation and SNR (Signal to Noise Ratio). This Element is thus satisfied.

of each of said plurality of wireless network nodes to simulate, without changing operating parameters of said at least one mobile node, different wireless communication conditions experienced by said at least one mobile node in actual operation.	

151. Hence, the devices are configured to wirelessly communicate with the wireless network nodes, and no other operating parameter on the UE or DUT is changed during the process.

152. Spirent, Anritsu, ANITE, and all other providers use a laptop or controller to turn on and control the simulation. For instance, some providers call this "controller," "Test Manager," other "AMS 32" according to the software referenced by the testing specification.[37]



RF Diagnostic Chamber with AMS 32 in Reference to Device List from Verizon[38]

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[37] CMW550 and AMS32 are referenced in MWVZ00001412.
[38] *Id.*

Table 2. Software Versions for Controller Platform

Controller Name	Software Version	Vendor
CDMA Interactive Functional Test Software *T4010S LTE FDD CA 2-13 RF Sup* *5973A IFT Scripts for LTE – CDMA InterRAT Operations*	4.5.0 v.1.0.0 8.1.0.0	Agilent/KeySight
VAS #01 (LTE Data Retry),* *VAS #02 (LTE SMS & LTE Suplementry Signalling),* *VAS #04 (LTE Band13 Data Throughput)* *,VAS #05 (AT commands),* *VAS #07 (LTE IMS Registration and Retry)** *VAS #08 (Supplementary Signalling and PCO)*	VAS#01.V30.481 VAS #02.v31.500 VAS#07.v30.481	ANITE
LTE Data Throughput Test Package *LTE Data Retry Test Package* *LTE SMS Test Package* *LTE Supplementary Signaling Test Package* *LTE IMS Registration and Retry Test Package* *Band 13 Supplementary RF Test Cases* *SV-LTE TRX Test Cases*	ME7834L-431 ME7834L-433 ME7834L-436 ME7834L-434 ME7834L-437 ME7834L-447 MX787311L-047	ANRITSU
ETSI 102.230. Protocol. *VZW LTE Multi-mode Smartphone UICC Interacation* *VZW LTE device SIM Application Interaction* *LTE CMW500 Network Simulator Controller*	5.0.2	COMPRION
Test Pack for VZW FDD13 supplementary RF conformance (TS8-KM920/921 *Test Pack for VZW FDD13 SVLTE supplementary RF conformance (sections 2.1.1 and 2.1.2) - (TS8-KM925)* *Test Pack for VZW LTE 3GPP Band 13 Supplementary RRM Conformance* *Test Pack for VZW data retry KF570* *Test Pack for VZW Suppl Signaling KF577* *Test Pack for VZW InterRAT Performance KF578* *Test Pack for VZW COMPLIANCE TEST PLAN LTE- RICH COMMUNICATION SERVICES DEVICES KAF74* *Test Pack for VZW FDD13 data throughput (TS8-KM922/927)* *Test Pack for VZW FDD13 SVLTE LTE Data w/1x Voice conformance (sections 2.1.3 and 2.2.2) - (TS8-KM926)* *Test Pack for VZW LTE SUPL 2.0 (CMW-KAF72)* *AMS32*	RF-LTE 3.90, (3.90.1 Signaling Adapter), RF-LTE 3.91 and RF-LTE 4.01 RF-LTE 3.90, (3.90.1 Signaling Adapter), RF-LTE 3.91 RRM 7.10 30.32.2 30.32.2 2.2/5.0 AMS32 + AMS32-K32	ROHDE & SCHWARZ
Test Manager *AirAccess* *AirAccess* *TAKSKIT C2K* *LTE Mobility Test Packs 1 & 2* *VZW SUPL2.0 Test Pack*	2.8.376 4.81.002 7.20 1.14.232 14.0.20.0 SUPL 2.0	SPIRENT
W2BI / QuikProbe 4G *Aeroflex / 7100 Instrument Software* *R&S / CMW500 LTE Signaling * (Callbox)*	1.4.0 25.1.0.0	WIB6 / AEROFLEX

153. Some of the test environments like Spirent use a computer that is linked to the Faders or attenuators through executable programs. Spirent uses a proprietary ".wce" file and sets the Faders in DEE mode operation. Commands are sent to the faders to control the wireless communication characteristics, such as signal strength, to simulate (without changing the operating parameters of the mobile phones) various wireless communication conditions experienced by the baseline radios and mobile phones under test.

154. In short, this Element 4 of claim 1 is readily satisfied by Verizon. As all the elements of claim 1 are met, Verizon infringes claim 1.

B. Discussion of Claims 3 and 4 of the '330 Patent

155. Claim 3 and Claim 4 discuss two wireless communication characteristics a) Signal Strength and b) SNR or Signal to Noise Ratio and Bit Error Rate (BER)

156. First, for Claim 3 to be satisfied, signal strength in dBm should be changed by the emulator, as shown in Figure 166. A fader is a device that test multiple paths through mathematical model-based signal attenuation as shown in Figure 17 below.

39 3.11 DOWNLINK UDP THROUGHPUT WITH VARIABLE REFERENCE MEASUREMENT CHANNELS VZ_TC_LTEB13DATATHRU_597

Definition

These tests verify that during an LTE data call the file transfer (using UDP) is successfully completed and the measured throughput rate at the UDP layer (using the LTE downlink channel) meets or exceeds the expected result when the reference measurement channel is dynamically adjusted based on the CQI and RI reported by the device. These tests are based on the fixed reference channel tests in section 3.4 and will include downlink transmit diversity and spatial multiplexing with AWGN and fading conditions. The test cases are summarized in Table below.

Test	Description
Test 1	Transmit diversity with low SNR
Test 2	Transmit diversity with fading per Test Number 1 in Table 8.2.1.2.1.3-2 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*
Test 3	Transmit diversity with fading per Test Number 2 in Table 8.2.1.2.1.3-2 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*
Test 4	Open loop spatial multiplexing with fading per Test Number 1 in Table 8.2.1.3.1.3-2 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*
Test 5	VOID
Test 6	VOID
Test 7	Closed loop spatial multiplexing (two layers) with fading per Test Number 1 in Table 8.2.1.4.1.3-4 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*
Test 8	Closed loop spatial multiplexing (two layers) with fading per Test Number 2 in Table 8.2.1.4.1.3-4 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*
Test 9	Closed loop spatial multiplexing (two layers) with 64-QAM modulation and fading (based on Test Number 1 in Table 8.2.1.4.1.3-4 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*)

Figure 17. Downlink Fading and UDP Throughput

157. One such model is Rayleigh, but there are many others found in literature.

158. Verizon uses a table for SNR and Propagation as described on pg. 72 on "LTE 3GPP Band13 Supplementary RF Conformance Test Plan_October 2017."[39]

---

[39] MWVZ00000171.

2. Follow the test procedure as per section 9.2.1.1.4.2 of 3GPP TS 36.521-1: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: conformance testing*, with the following exceptions:
    1. Set the parameters of bandwidth, reference Channel, the propagation condition, antenna configuration and the SNR according to Table 9.2.1.7-1 of 3GPP TS 36.101: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment(UE); Radio Transmission and Reception*, Release 12.

159. As indicated in the following table:

3GPP TS 36.521-1 version 13.1.0 Release 13 2000 ETSI TS 136 521-1 V13.1.0 (2016-05)

Table 9.2.1.7.3-1: PUCCH 1-0 static test (FDD)

Parameter		Unit	Test 1		Test 2	
Bandwidth		MHz	10			
PDSCH transmission mode			1			
Downlink power allocation	ρ_A	dB	0			
	ρ_B	dB	0			
	σ	dB	0			
Propagation condition and antenna configuration			AWGN (1 x 2)			
SNR (Note 2)		dB	-1	0	20	21
$\hat{I}_{or}^{(j)}$		dB[mW/15kHz]	-99	-98	-78	-77
$N_{oc}^{(j)}$		dB[mW/15kHz]	-98		-98	
Max number of HARQ transmissions			1			
Physical channel for CQI reporting			PUCCH Format 2			
PUCCH Report Type			4			
Reporting periodicity		ms	N_{pd} = 5			
cqi-pmi-ConfigurationIndex			6			

Note 1: Reference measurement channel RC.1A FDD according to Table A.4-1 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1.
Note 2: For each test, the minimum requirements shall be fulfilled for at least one of the two SNR(s) and the respective wanted signal input level.

The normative reference for this requirement is TS 36.101 [2] clause 9.2.1.7.

160. Clearly, Table 9.2.1.7.3-1 depicts several AWGN values to be used to test the UE and validate its performance.

161. Therefore Claim 3 and Claim 4 are infringed by Verizon.

<table>
<tr><td>Claim 3</td><td></td></tr>
<tr><td>The system of claim 1, wherein said wireless communication characteristics include a signal reception sensitivity.</td><td rowspan="3">Among the wireless communication characteristics that the attenuators and faders manipulate and emulate during testing on the Verizon systems include signal reception sensitivity, signal transmission strength, signal-to-noise ratio and bit error rate.

Thus, Verizon’s system satisfies these claims.</td></tr>
<tr><td>Claim 4</td></tr>
<tr><td>The system of claim 1, wherein said wireless communication characteristic includes at least one of signal transmission strength, signal-to-noise ratio (SNR), and bit error rate (BER).</td></tr>
</table>

XVI. THE BACKGROUND AND IMPORTANCE OF THE ’417 PATENT: NO VIABLE ALTERNATIVE

162. LTE as opposed to earlier mobile communications technologies only uses hard handovers.

163. This means that the LTE infrastructure / network must at all times inform the UE when a handover will occur and the target eNodeB to which the UE will be handover.

164. This notification needs to be done at the optimal time, before entering into the coverage area of the target eNodeB.

165. The more mistakes are made with setting up a target, the more dropped connections and failures will occur in LTE.

166. Hence, an appropriate more proactive protocol is required like the one proposed in the ’417 patent to make LTE a viable alternative.

A. Insights to the ’417 Patent

167. This patent covers handover using ghost entities, called Ghost Mobile Node and Ghost Foreign Agent, and predicting or anticipating handover.

168. The ghost entities work together to allocate resources pro-actively instead of reactively, at all layers of the protocol stack, but most importantly triggering resources before a mobile device reaches a new coverage area of a Foreign Agent"

169. The Ghost Mobile Node sends an "IP replica" message that contains all credentials, context, and additional information that is sent to the Home Agent on behalf of the Mobile Node.

170. The replica message once sent to the Home Agent is generated when the Mobile Node is about to exit the range or the servicing Foreign Agent and resources are allocated to the closest or optimal Foreign Agent where it has to move next.

171. Physical handoff is not assumed to be optimal, what is required by the '417 patent is layer-3 handover to take place before a physical handover has taken place.

172. For starters, the patent uses an algorithm shown in the following figure:

The following is an example of an algorithm that can be used in the ghost-mobile node to find a closest foreign agent using the measurement vector $z_k=[x\ y]^T$:

```
g-MN (Home Address, HomeAgentAddress)
    while (true) do
        FA FindClosestFA(MN)
        if distance (FA, MN) within threshold then
            HFA FindHighestFA(FA, HomeAgentAddress)
            Register(FA, HomeAddress, HFA)
        end
```

Those of ordinary skill in the art will readily recognize that other techniques beside the Kalman filter can be used by the ghost-mobile node **220** for location prediction. Other techniques for predicting a location of the mobile node **250** include, for example, neural networks, linear prediction mechanisms, and modeling of stochastic processes.

173. A Kalman filter is used in computing the distance to the closest Foreign Agent to the mobile node and based on that threshold or within a range a replica registration message is sent to the Foreign agent, based on the predicted location.

174. A Kalman filter is a multi-layer filter of *N*-th order.

175. A much simpler filter is a linear filter with one or two coefficients, for instance in LTE a filter called L3-filter is used.

176. Verizon makes the use of this filter a requirement:[40]

[40] MWVZ00000046.

2. Follow steps 1 through 8 in section 9.1.1.1.4.2 of 3GPP TS 36.521-3: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: Radio Resource Management conformance testing* using the message contents defined in section 9.1.1.1.4.3 of 3GPP TS 36.521-3: *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: Radio Resource Management conformance testing* with the exceptions noted below:
    1. L3 filtering shall be enabled for RSRP measurements with the coefficient set to k=8.
    2. Set the parameters for Test 1 per Table 2.1.2-1 and Table 2.1.2-2 below.
    3. The UE shall be set up to report RSRP results for Cells 1, 2, and 3 for a

given test.

4. UE measurements shall be taken for each cell in a given test until the appropriate confidence level defined in Annex G.2 of 3GPP TS 36.521-3 is achieved.
5. For each test, the RSRP values reported for all cells shall be recorded.
6. For each set of measurements reported by the device, the test platform shall calculate:
    1. RSRP for Cell 2 RSRP for Cell 1
    2. RSRP for Cell 3 RSRP for Cell 1 (if Cell 3 is used for the test)
7. The test platform shall report the following statistics for informational purposes:
    1. Mean RSRP value reported for each cell.
    2. Maximum RSRP value reported for each cell.
    3. Minimum RSRP value reported for each cell.
    4. Standard deviation for the RSRP values reported for each cell.
    5. RSRP values versus time reported for each cell.

3. Repeat steps 1.) and 2.) for Test 2 per Table 2.1.2-1 and Table 2.1.2-3 for propagation conditions AWGN, EPA5, and EVA70.
4. Repeat steps 1.) and 2.) for Test 3 per Table 2.1.2-1 and Table 2.1.2-4 for propagation conditions AWGN, EPA5, and EVA70.
5. Repeat steps 1.) and 2.) for Test 4 per Table 2.1.2-1 and Table 2.1.2-5 for propagation conditions AWGN, EPA5, and EVA70 with the following exception: connected-mode DRX shall be enabled.

177. The RSRP[41] is used to compute the next measurement report. Verizon actually defines the accuracy levels required for the filter.

[41] Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ) are measured by the UE at the measurement report interval.

1.6.4.1.1.1 RSRP ABSOLUTE ACCURACY VZ_REQ_LTEB13NAC_6420

The device shall meet the requirements in the table below for the absolute accuracy of RSRP measurements in RRC_CONNECTED mode (with and without connected mode DRX) and with L3 filtering enabled.

Parameter	Unit	Accuracy [dB]		Conditions[1]
		0° to +40°C	-10° to +55°C	Band 13
			-30° to +60°C	Io
Intra-Frequency RSRP for Ês/Iot ³ -6 dB	dBm	±4	±6	-121dBm/15kHz & -50dBm/ $BW_{Channel}$
Inter-Frequency RSRP for Ês/Iot ³ -6 dB	dBm	±4	±6	-121dBm/15kHz & -50dBm/ $BW_{Channel}$
Note 1. Io is assumed to have constant EPRE across the bandwidth.				

The device shall meet the accuracy requirements in the table below for the mean of the

178. The L3 Filtering is enabled when the phone is in connected mode.

179. LTE defines two modes, idle (RRC_IDLE) or connected (RRC_CONNECTED).

180. The L3-filter can be represented as an equation as defined by the 3GPP specification TS 36.331 on 5.5.3.2.

$$F_n = (1-a) \cdot F_{n-1} + a \cdot M_n$$

where

M_n is the latest received measurement result from the physical layer;

F_n is the updated filtered measurement result, that is used for evaluation of reporting criteria or for measurement reporting;

F_{n-1} is the old filtered measurement result, where F_0 is set to M_1 when the first measurement result from the physical layer is received; and

$a = 1/2^{(k/4)}$, where k is the *filterCoefficent* for the corresponding measurement quantity received by the *quantityConfig*;

181. This type of filtering uses the prior filtered measurement and a coefficient with the current measurement, to estimate, or predict the F_n or updated filtered measurement result.

182. Additionally, the LTE Specification defines a “TimetoTrigger” value.

183. Verizon includes a test covering two cells: Cell A and Cell B. Cell A with TAI-1 (Tracking Area Identifier 1) and TAI-2 (Tracking Area Indentifier-2) triggering Handover (HO) as explained in "LTE_Supplementary_Signaling_Conformance_TestPlan_Feb2019" on Page 64 (MWVZ00001234).

Pre-Conditions (Step 1)

Procedures (Step 1)

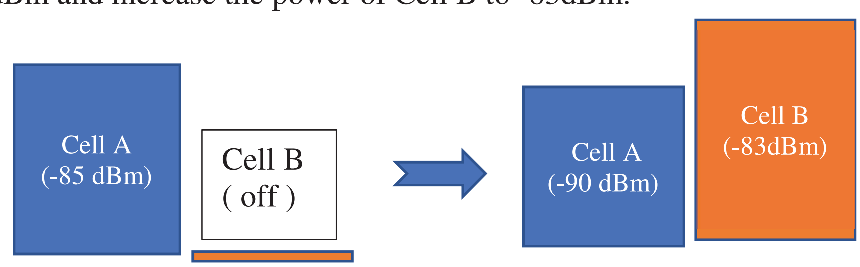
System Simulator:
- cell A (belongs to TAI-1, home PLMN) transmit power is set to -85 dBm;
- cell B (belongs to TAI-1, home PLMN) transmit power is set to "off".

Step	Procedure	Message Sequence		Verdict
		U - S	Message	
1	Start with UE in RRC Connected state on cell A and connect the UE to a PC such that there is data to be sent to maintain RRC connection	-	-	N/A
2	Reduce the power on cell A to -90dbm, set cell B power on at -83dbm. (there is no need to configure HO trigger as we simply use a forced HO).	-	-	N/A
3	The TE simulator sends RRCConnectionConfiguration message on cell A to direct the UE to HO to cell B	<=	*RRCConnectionReconfiguration*	N/A
4	The UE sends RRCConnectionReconfigurationComplete on cell B	=>	*RRCConnectionReconfigurationComplete*	N/A
5	The TE simulator transmits MIB, SIB1, and SIB2 periodically (each SIB is on their own, no bundling) without transmitting SIB3, SIB5 or SIB8: • SIB1 specifies SIB3/5/8 confoguration so that UE will try to decode them	-	-	N/A
6	Verify that the RRC connection continues for the next 5 minutes without any RLF or RRC re-establishment.	-	-	N/A
7	Power off the device			

Expected Results (Step 1)

184. In this Handover process, the Cell A is turned on at -85dBm, and Cell B is turned off.

185. According to the test (MWVZ00001234), the test Emulator reduces power of Cell A to -90dBm and increase the power of Cell B to -83dBm.



186. This process triggers and forces handover to occur. However, an **RRCConnectionReconfiguration** message is sent from Cell A to Cell B before mobile node enters the coverage area of Cell B (which in this test case corresponds to -83dBm). This test, therefore, simulates the handover preparations required by claim 1 of the '417 Patent **BEFORE** entering into Cell B coverage area.

187. The reason why this happens before is because, Cell A has to still send the handover command with **RRCConnectionReconfiguration** message to the device, before it switches over to Cell B. As the Cell A is still covering the area for the UE, and it is about to switch to Cell B, and before this takes place the Cell A needs to anticipate and initiate/perform handover.

188. The LTE Events and measurement reports are provided in the Table below:[42]

Table 3. Measurement Report and LTE Events

Event Type	Description
Event A1	Serving becomes better than threshold
Event A2	Serving becomes worse than threshold
Event A3	Neighbour becomes offset better than serving
Event A4	Neighbour becomes better than threshold
Event A5	Serving becomes worse than threshold1 and neighbour becomes better than threshold2
Event A6	Neighbour become offset better than S Cell (This event is introduced in Release 10 for CA)
Event B1	Inter RAT neighbour becomes better than threshold
Event B1-NR	NR neighbour becomes better than threshold
Event B2	Serving becomes worse than threshold1 and inter RAT neighbour becomes better than threshold2
Event B2-NR	Serving becomes worse than threshold1 and NR neighbour becomes better than threshold2
Event C1	CSI-RS resource becomes better than threshold
Event C2	CSI-RS resource becomes offset better than reference CSI-RS resource
Event W1	WLAN becomes better than a threshold
Event W2	All WLAN inside WLAN mobility set becomes worse than threshold1 and a WLAN outside WLAN mobility set becomes better than threshold2
Event W3	All WLAN inside WLAN mobility set becomes worse than a threshold

[42] TS 3GPP 36.331 Section 5.5.4.

Event V1	The channel busy ratio is above a threshold
Event V2	The channel busy ratio is below a threshold
Event H1	The Aerial UE height is above a threshold
Event H2	The channel busy ratio is below a threshold

189. These events are submitted by the UE based on the filter-coefficient value which is also set by the Service eNodeB.

190. The mechanism consists of:

a. First, the eNodeB Serving a UE sends a **RRCConnectionReconfiguration** message to the UE with the event or events need to be reported by the UE to the eNodeB.

b. All these events occur within a specified "TimetoTrigger" value, which is defined by the eNodeB as well. Depending on multiple parameters including the TriggerQuantity parameter, which is set by the ENodeB, the UE waits for a decision to be made by the serving eNodeB.

191. In my opinion, handover decisions always occur **before** arriving to the coverage area of the target cell for several reasons:

a. The RSRP value is predicted and Measurement Reports are sent to the serving eNodeB from the UE.

```
+-rrcConnectionReconfiguration ::= SEQUENCE
  +-rrc-TransactionIdentifier ::= INTEGER (0..3) [0]
  +-criticalExtensions ::= CHOICE [c1]
   +-c1 ::= CHOICE [rrcConnectionReconfiguration-r8]
    +-rrcConnectionReconfiguration-r8 ::= SEQUENCE [100000]
     +-measConfig ::= SEQUENCE [01010111111] OPTIONAL:Exist
     | +-measObjectToRemoveList ::= SEQUENCE OF OPTIONAL:Omit
     | +-measObjectToAddModList ::= SEQUENCE OF SIZE(1..maxObjectId[32]) [1]
     | | +-MeasObjectToAddMod ::= SEQUENCE
     | |  +-measObjectId ::= INTEGER (1..maxObjectId[32]) [1]
     | |  +-measObject ::= CHOICE [measObjectEUTRA]
     | |   +-measObjectEUTRA ::= SEQUENCE [100000]
     | |    +-carrierFreq ::= INTEGER (0..maxEARFCN[65535]) [6300]
     | |    +-allowedMeasBandwidth ::= ENUMERATED [mbw25]
     | |    +-presenceAntennaPort1 ::= BOOLEAN [FALSE]
     | |    +-neighCellConfig ::= BIT STRING SIZE(2) [01]
     | |    +-offsetFreq ::= ENUMERATED [dB0] OPTIONAL:Exist
     | |    +-cellsToRemoveList ::= SEQUENCE OF OPTIONAL:Omit
     | |    +-cellsToAddModList ::= SEQUENCE OF OPTIONAL:Omit
     | |    +-blackCellsToRemoveList ::= SEQUENCE OF OPTIONAL:Omit
     | |    +-blackCellsToAddModList ::= SEQUENCE OF OPTIONAL:Omit
     | |    +-cellForWhichToReportCGI ::= INTEGER OPTIONAL:Omit
     | +-reportConfigToRemoveList ::= SEQUENCE OF OPTIONAL:Omit
     | +-reportConfigToAddModList ::= SEQUENCE OF SIZE(1..maxReportConfigId[32]) [1]
     | | +-ReportConfigToAddMod ::= SEQUENCE
     | |  +-reportConfigId ::= INTEGER (1..maxReportConfigId[32]) [1]
     | |  +-reportConfig ::= CHOICE [reportConfigEUTRA]
     | |   +-reportConfigEUTRA ::= SEQUENCE
     | |    +-triggerType ::= CHOICE [event]
     | |    | +-event ::= SEQUENCE
     | |    |  +-eventId ::= CHOICE [eventA3]
     | |    |  | +-eventA3 ::= SEQUENCE
     | |    |  |  +-a3-Offset ::= INTEGER (-30..30) [0]
     | |    |  |  +-reportOnLeave ::= BOOLEAN [FALSE]
     | |    |  +-hysteresis ::= INTEGER (0..30) [0]
     | |    |  +-timeToTrigger ::= ENUMERATED [ms640]
     | |    +-triggerQuantity ::= ENUMERATED [rsrp]
     | |    +-reportQuantity ::= ENUMERATED [both]
     | |    +-maxReportCells ::= INTEGER (1..maxCellReport[8]) [1]
     | |    +-reportInterval ::= ENUMERATED [ms1024]
     | |    +-reportAmount ::= ENUMERATED [r1]
```

Figure 18. RRCConnectionREconfiguration Message

b. As shown in Figure 18, the a3-offset, hysteresis, timeToTrigger, triggerQuatity are set by the eNodeB, including a reportInterval.

c. The a3-offset and hysteresis are used together with the reportInterval, reportQuantity as follows:

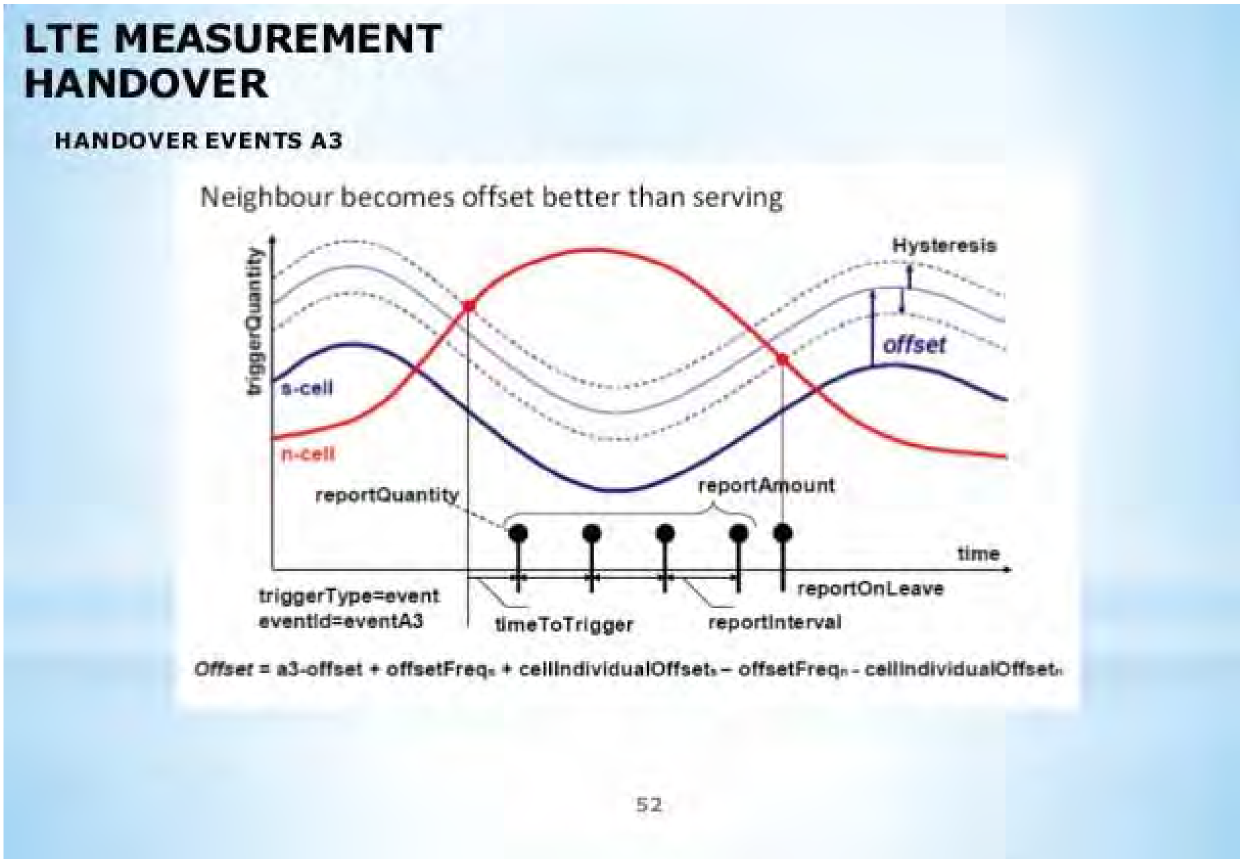


Figure 19 . A3 Handover with a3-offset, hysteresis, other parameters

d. As shown in the diagram, it is then the serving eNode B that defines the coverage area for itself and the neighbors.

e. The serving eNodeB determines, timeToTrigger (depending on mobility state of the UE), report interval, report quantity, and report amount.

192. In general, coverage area is not only defined by the RSRP received by the UE, as the UE is connected to the Serving eNodeB at all times, until after reporting an event (e.g. A2, A3, whatever the serving cell defines), then it will be commanded by an **RRCConnectingReconfiguration** message to switch to a new cell, or a target cell.

193. Coverage area is then defined by the serving eNodeB until offset, hysteresis, TimetoTrigger, and other parameters are met.

194. The RRCConnectionReconfiguration message during handover includes a MobilityControlInfo field with the "TargetPhysCellId" to handoff to.

```
MobilityControlInfo ::= SEQUENCE {
   targetPhysCellId PhysCellId,
   carrierFreq CarrierFreqEUTRA OPTIONAL, -- Cond HO-toEUTRA2
   carrierBandwidth CarrierBandwidthEUTRA OPTIONAL, -- Cond HO-toEUTRA
   additionalSpectrumEmission AdditionalSpectrumEmission OPTIONAL, -- Cond HO-toEUTRA
   t304 ENUMERATED {
      ms50, ms100, ms150, ms200, ms500, ms1000,
      ms2000, spare1},
   newUE-Identity C-RNTI,
   radioResourceConfigCommon RadioResourceConfigCommon,
   rach-ConfigDedicated RACH-ConfigDedicated OPTIONAL, -- Need OP
   ...,
   [[ carrierFreq-v9e0 CarrierFreqEUTRA-v9e0 OPTIONAL -- Need ON
   ]],
   [[ drb-ContinueROHC-r11 ENUMERATED {true} OPTIONAL -- Cond HO
   ]]
}
```

Figure 20. Mobility Control Info on RRCReconfigurationMessage

195. LTE uses hard handovers; hence, proper identification of the target cell is required for proper handover processing.

196. Another element that is important to determine coverage is the capacity for a UE to create a DL and UL (Downlink and Uplink) channels. Handover starts when:

a. UE is in connected state and a data call is up. Data packets are transferred to/from the UE to/from the network in both directions (DL as well as UL).

197. That means that any UE is in **RRC_CONNECTED** state to perform handoff. Any UE in RRC_IDLE state does cell reselection, which is different from handover.

198. In the Verizon case there are several components associated with handover:[43]

[43] Reqs_LTE_3GPP_Band13_NetworkAccess_Feb2019.pdf.

a. Minimized Drive Test (MDT) as part of Release 10, a UE must include Location Information in all Measurement Reports when in a RRC Connected State (RRC_CONNECTED).[44]

1.3.2.24.3.2 Overall Requirements VZ_REQ_LTEB13NAC_38230

The device shall support ALL LTE MDT requirements (stage 2, mandatory and optional) that apply to device as defined in the release 10 version of 3GPP TS *37.320: Evolved Universal Terrestrial Radio Access (E-UTRA);Radio measurement collection for Minimization of Drive Test; Overall description; Stage 2.*

- The ability of the UE to include location information as part of UE radio measurement reporting in RRC connected state, including RACH report
- Configuration of a logging area
- The ability of the UE to log radio measurements during the UEs RRC idle state

1.3.2.24.3.3 MDT Capability VZ_REQ_LTEB13NAC_38231

The device shall support UE capability for MDT as defined in section 4.3.13 in the release 10 version of 3GPP TS *36.306: Evolved Universal Terrestrial Radio Access (E-UTRA);UE Radio Access Capabilities*) and section 6.3.6 of the release 10 version of 3GPP TS 36.331: *Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) Protocol Specification*:

- UE-BasedNetwPerfMeasParameters-r10
    - loggedMeasurementsIdle-r10
    - standaloneGNSS-Location-r10

b. UE Location Information. The LocationInfo value shall be set if "includeLocationInfo" is turned on. However, all failure reports must include a LocationInfo field.[45]

[44] MWVZ00001988.
[45] *Id.*

1.3.2.24.3.4 LocationInfo for measurement report VZ_REQ_LTEB13NAC_38232

The device shall set *LocationInfo* in measurement report (immediate reporting) if *includeLocationInfo* is configured in the corresponding *reportConfig* for the *measId* as stated in section 5.5.5, 6.2.2 in the release 10 version of 3GPP TS 3GPP TS 36.331: *Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) Protocol Specification.*

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199. What this means is that Verizon has a mapping of signal strength to every location.

200. Additionally. Self-Organizing Networks (SON) and Automatic Neighbor Relationships contribute to creating optimized cell coverage and mixing macro-, pico- and femto-cells for optimal performance. Optimized handovers are required for VoLTE deployments as handover policies vary from carrier to carrier, and with voice having different requirements than data, proper SON strategies are a must.

201. Verizon's Vendors (e.g. Cisco) defines that:

a. According to Cisco: "Major network vendors have responded to the 3GPP SON standards initiative by implementing distributed SON (dSON) functionality in their eNBs and small cells. For example, dSON solutions for LTE manage the immediate environment of the eNB or small cell, which means they cover rapid local activities, such as ANR and PCI, for LTE only. Deployment is quicker, with initial configuration handled automatically. Some operators feel that this is sufficient and do not understand the inherent limitations of such an approach. That is, dSON solutions for LTE and small cells typically only interact with other

sites within their own technology and vendor. The 3GPP standard also proposed a centralized SON (cSON) that would operate at the network management layer".[46]

b. Also "Cisco believes that full optimization requires a hybrid of centralized and distributed optimization. The centralized function can optimize interactions, such as neighbor relations and interference, between technology layers and across multiple vendors, while steering the distributed functionality. This approach can achieve a superior result based on a wider view of the entire network."[47]

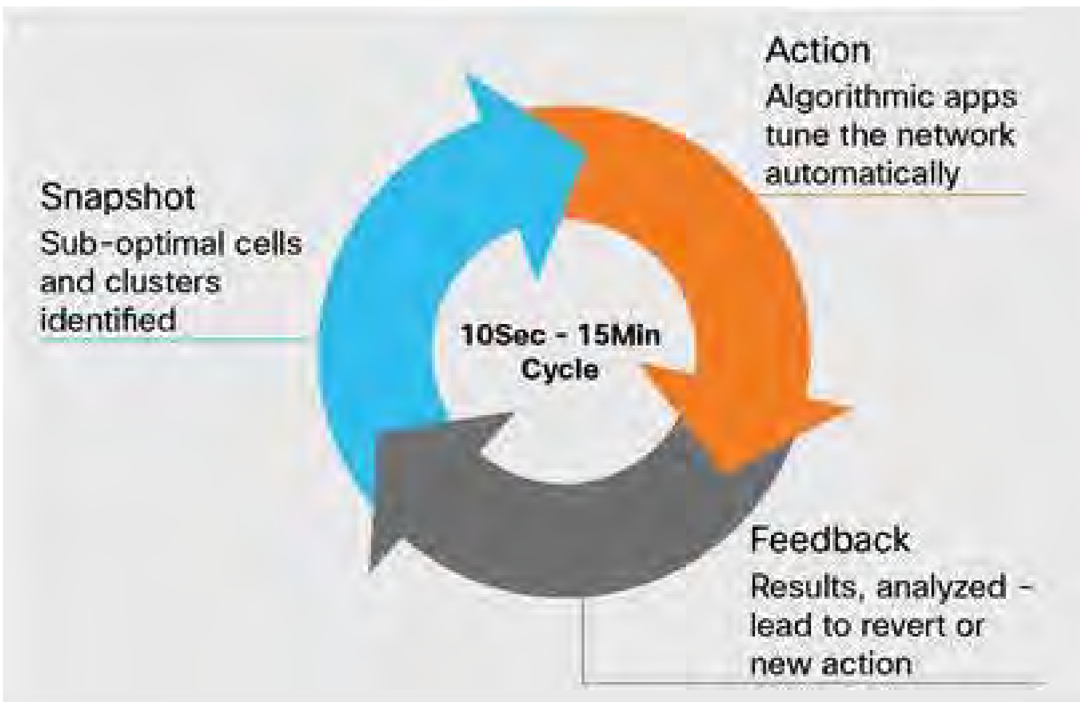


Figure 21. Self-Organizing Networks (SON)

202. Now that we understand how the Handover process works, I will introduce X2 and S1 handover, which are illustrated in Figure 22 through Figure 25.

---

[46] https://www.cisco.com/c/en/us/solutions/collateral/service-provider/son-architecture/white-paper-c11-733194.html.

[47] https://www.cisco.com/c/en/us/solutions/collateral/service-provider/son-architecture/white-paper-c11-733194.html.

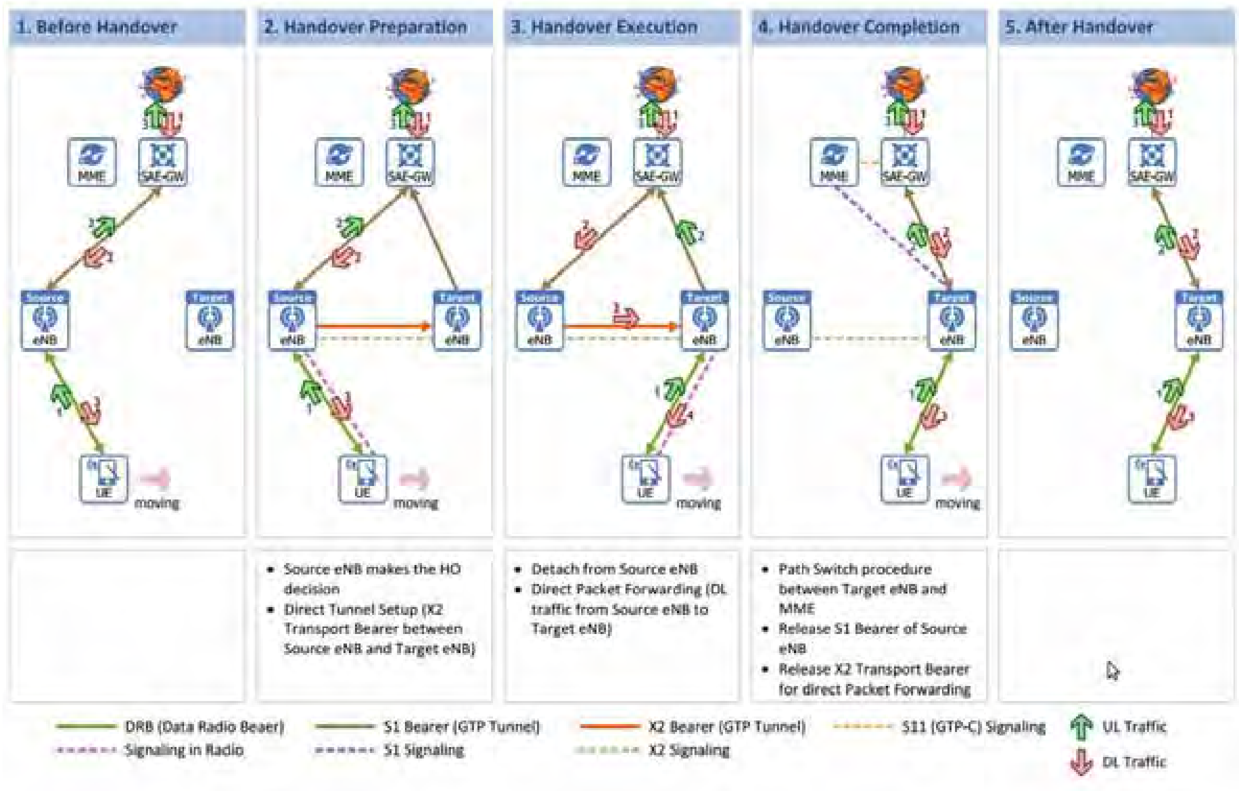


Figure 22. X2 Handover – Steps in High-Level[48]

203. Whether X2 or S1, LTE handovers follow three basic steps:

a. Handover Preparation

b. Handover Execution

c. Handover Completion

204. The handover preparation steps can be broken down further into the following steps:

a. For an X2 handover, once the eNodeB detects an A3, A2, or any other event, the Source eNodeB determines when to handover and ultimately makes the Handover Decision. (See, e.g., Figure 23)

b. Once the Handover Decision is made by the Source eNodeB, the source eNodeB sends a HANDOVER REQUEST to a target eNodeB. The HANDOVER

[48] http://www.3glteinfo.com/intra-lte-handover-using-x2-interface/.

REQUEST sent to the Target eNodeB includes a target container with information from the UE including Security Capabilities, Access parameters, etc. In other words, a copy of the UE's context is copied into the Handover Request and forwarded to the Target eNodeB by the Source eNodeB. (See, e.g., Figure 23)

c. The decision to send a HANDOVER REQUEST for a UE to a target eNodeB is based on a handover algorithm which is designed to detect various handover events, e.g., A2, A3, as well as other events specified in the LTE Specification (3GPP Release 8 or greater). Within the framework of the LTE Specification, each network operator may have its own handover algorithm for each type of handover event specified in the LTE specification.

d. The Target eNodeB receives the HANDOVER REQUEST and determines whether it has sufficient resources to handle the handover request. Once the Target eNodeB receives the HANDOVER REQUEST, it sends a HANDOVER REQUEST ACKNOWLEDGEMENT to the Source eNodeB. If the Target eNodeB has sufficient resources, it will accept the handover.

e. In the event of an S1-AP handover (Figure 25 herein), a HANDOVER REQUEST goes from the Source eNodeB to the MME and then to the Target eNodeB over the S1 interface. Therefore, the difference between an X2 and an S1-AP handover is that in S1-AP handover an MME (Mobility Management Entity) is involved in the handover, whereas an X2 handover is carried out over the X2 interface directly between the Source eNodeB and Target eNodeB.

f. Once the HANDOVER REQUEST ACKNOWLEDGEMENT is received and handover is accepted by the Target eNodeB, the Source EnodeB sends a

Handover Command by way of the RRCConnectionReconfiguration message to the UE via the Radio Resource Control channel. The RRCConnectionReconfiguration message contains identification information for the Target eNodeB, measurement configuration information for handover events within the coverage area of the Target eNodeB, and a Security Algorithm.

g. After the preparation step, the handover execution steps are carried out as shown in Figure 22 through Figure 25. The completion step is then carried out, which is nothing but finalizing the process of moving all the bearers and switching over to the target and moving all Data Radio Bearer (DRB) and tunnels to the target eNodeB. (See Figure 22 through Figure 25.)

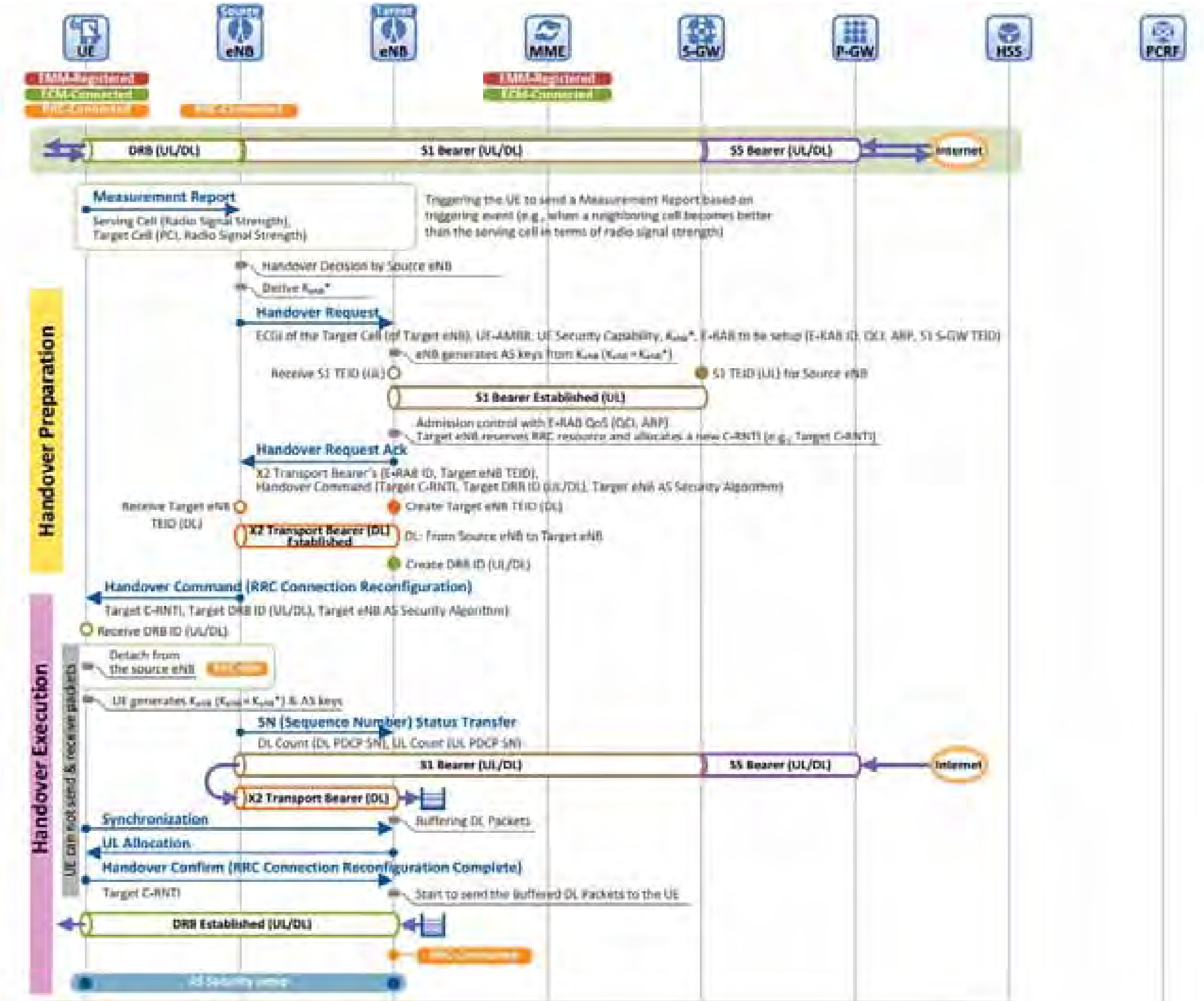


Figure 23. X2 Handover - Handover Preparation and Handover Execution

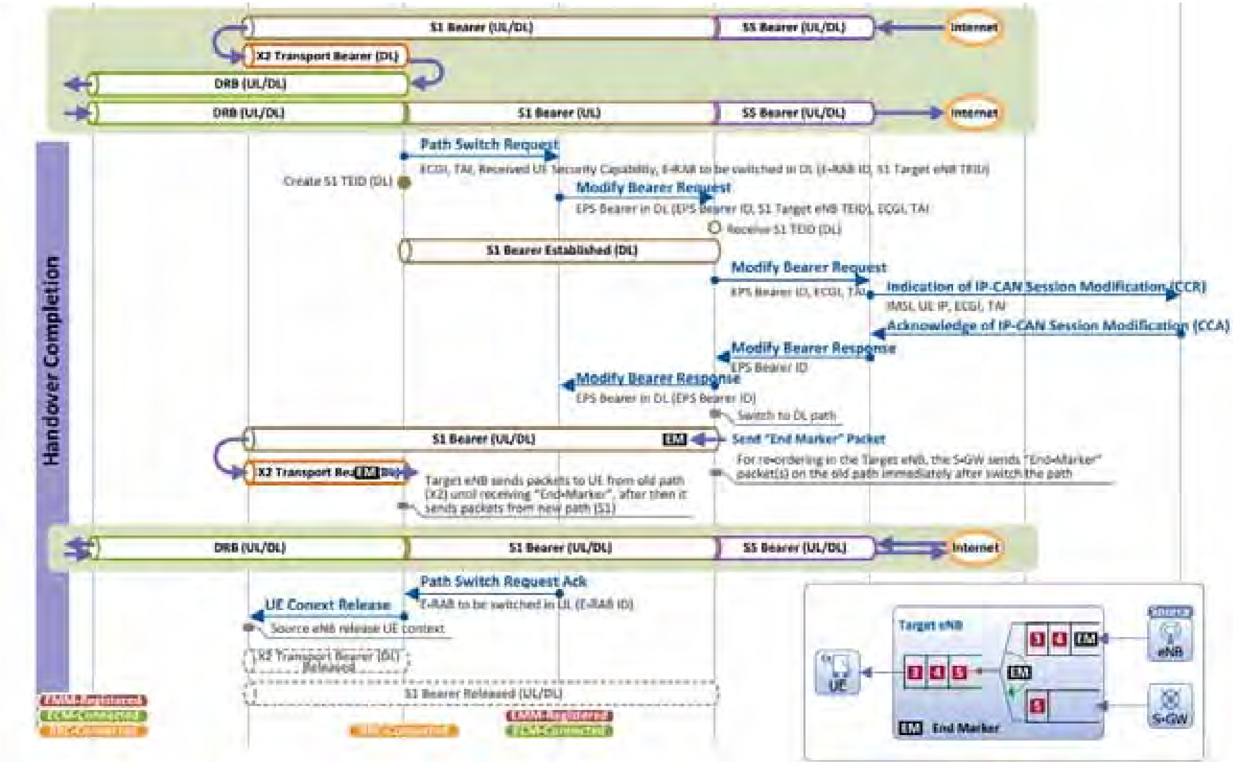


Figure 24. X2 Handover Completion

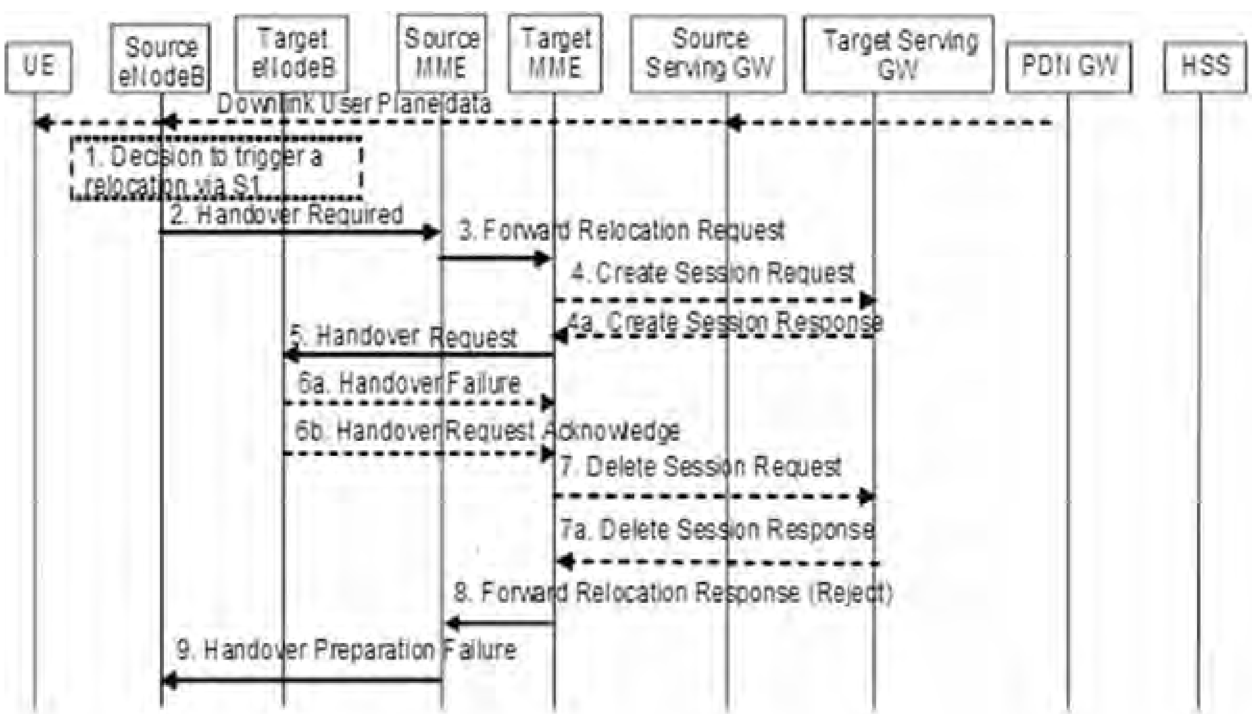
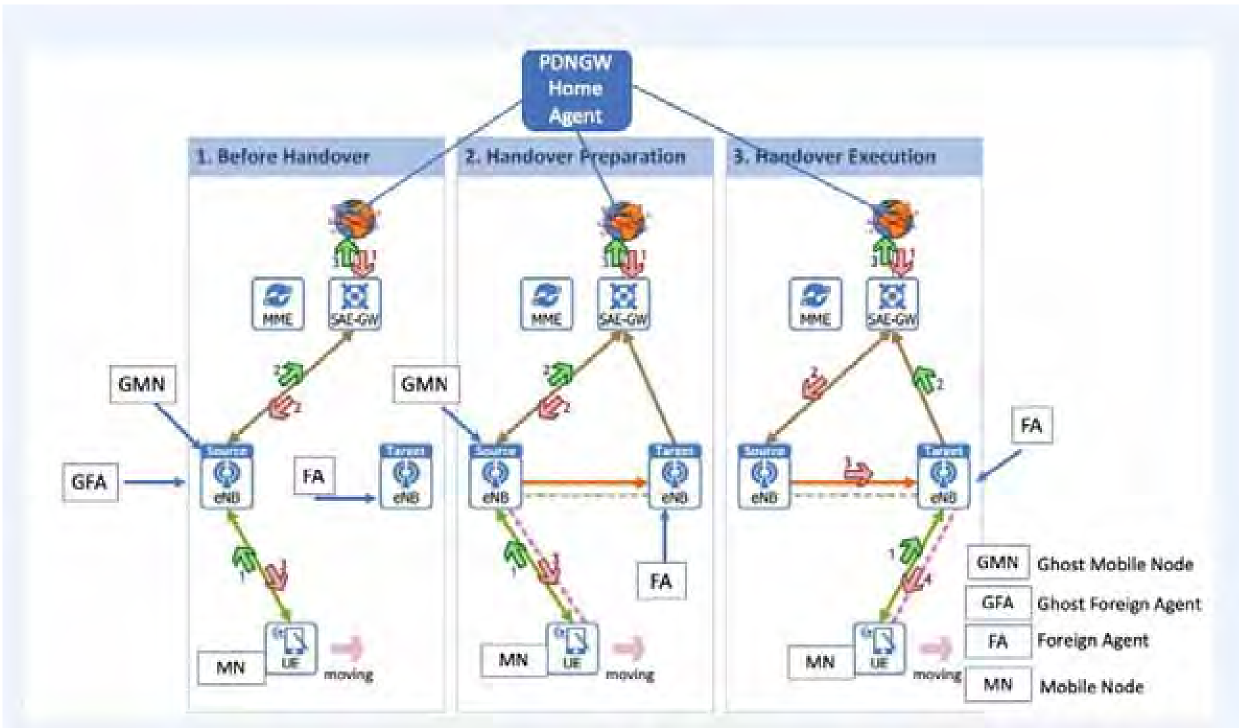


Figure 25. S1 HAndover with MME involvement

XVII. THE COMPARISON OF THE ACCUSED LTE SYSTEM AND X2 and S1 AP HANDOVER PROCESSES TO THE CLAIMS OF THE '417 PATENT

205. The Asserted Claims of the '417 Patent can be mapped to the Verizon LTE network as illustrated in the diagram below.



A. Discussion of Claim 1 of the '417 Patent

206. I will use the definitions found on Table 1 to determine infringement on X2 and S1 AP handover.

Claim 1	Basic Opinion
Preamble: A system for communicating between a mobile node and a communication network; the network having at least one communications network node that is interconnected using a proxy mobile internet protocol (IP), comprising:	Verizon has shown to have an LTE System with a communication network with millions of mobile nodes (e.g. phones) that are interconnected using a proxy mobile IP protocol (e.g. Proxy Mobile IPv6, others,). This element is satisfied.

207. Verizon specifies as part of its requirements the use of LTE's X2 and S1 handover. These handovers set entities like eNodeB and MME to act on behalf of the mobile node, indeed working as a proxy. Use of proxies is not a novelty, as Proxy Mobile IPv6 is part of the requirements set by Verizon for all LTE products (Reqs_LTE_3GPP_Band13_NetworkAccess_Feb2019, pg. 81).

2. IP mobility shall be handled by GTP and/or Proxy Mobile IPv6, which are network capabilities (i.e. no device impact). Refer to 3GPP TS 29.274: *3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling*

1. Element 1 Discussion

208. The first element in the system is a mobile node.

Element 1	BASIC OPINION
At least one mobile node:	THIS ELEMENT IS SATISFIED

209. All phone, tablets, iOT devices, and other connected devices in Verizon LTE network qualify as mobile nodes.

2. Element 2 Discussion

Element 2	BASIC OPINION
At least one home agent:	THIS ELEMENT IS SATISFIED

210. A home agent is defined as the network that assigns an IP Address upon registration or first attachment to the network by the PDN Gateway.

211. As a requirement, Verizon establishes that during the attach procedure the first default bearer and the PDN connectivity request associate corresponding IP Addresses, which will remain the same. See "Reqs_LTE_3GPP_Band13_NetworkAccess_Feb2019":

> The device shall be capable of simultaneously supporting at least one unique IPv6 address and a unique IPv4 address for each PDN connection (Pg. 76).
>
> When establishing default bearers and their associated IP addresses, the device shall use the Attach Procedure to create the first default bearer and the PDN Connectivity Request procedure to request subsequent default bearers. Refer to 3GPP TS 24.301: Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 for additional details. (Pg. 81)

212. This is defined on Pg. 171 of "Reqs_LTE_3GPP_Band13_NetworkAccess_Feb2019" of the same requirements document as follows:

> "The device shall be capable of supporting a unique IPv6 address and a unique IPv4 address for each PDN connection."

213. A Home Agent is the agent that resides in the home network and functions as the internet gateway or router.

> A home agent is a router on a mobile node's home network which tunnels datagrams for delivery to the mobile node when it is away from home. It maintains current location (IP address) information for the mobile node. It is used with one or more foreign agents.

214. These functions are the same for X2 and S1-AP handovers.

215. This is the same function found in the PDN Gateway that is part of Verizon's LTE network.

3. Element 3 Discussion

Element 3	BASIC OPINION
At least one foreign agent:	THE eNODEB/S-GW COMPONENT BY ITSELF OR IN CONJUNCTION WITH THE S-GW. THIS ELEMENT IS SATISFIED.

216. As defined by the Markman order a "Foreign Agent" is "a network node on a visited network that assists the mobile node in receiving communications."

217. This is clear from the Mobile IPv4 and Mobile IPv6 perspective a visited network is a network other than the home network.

218. A visited network or a foreign network, in Mobile IPv4 adheres to the definition "A foreign network is the network in which a mobile node is operating when away from its home network." (RFC 2002, IP Mobility Support, Pg. 6.)

219. In general, when a mobile phone moves away from its home network and away from the home agent's local network, it will be in a foreign network or visited network.

220. Roaming also involves visiting a foreign network. When you roam you travel to a visited network but the same is true when you move to a new eNodeB because the IP address from the eNodeB and S-GW are different from the PDN Gateway that is the UE's home agent. Further, in LTE, a GPRS Tunnel Protocol ("GTP") tunnel is required to communicate between the PDN Gateway and S-GW, and from the S-GW to the eNodeB, as well as in the opposite direction.

221. In general, a UE connected to any eNodeB will require a GTP Tunnel to send and receive IP Packets from the PDN Gateway.

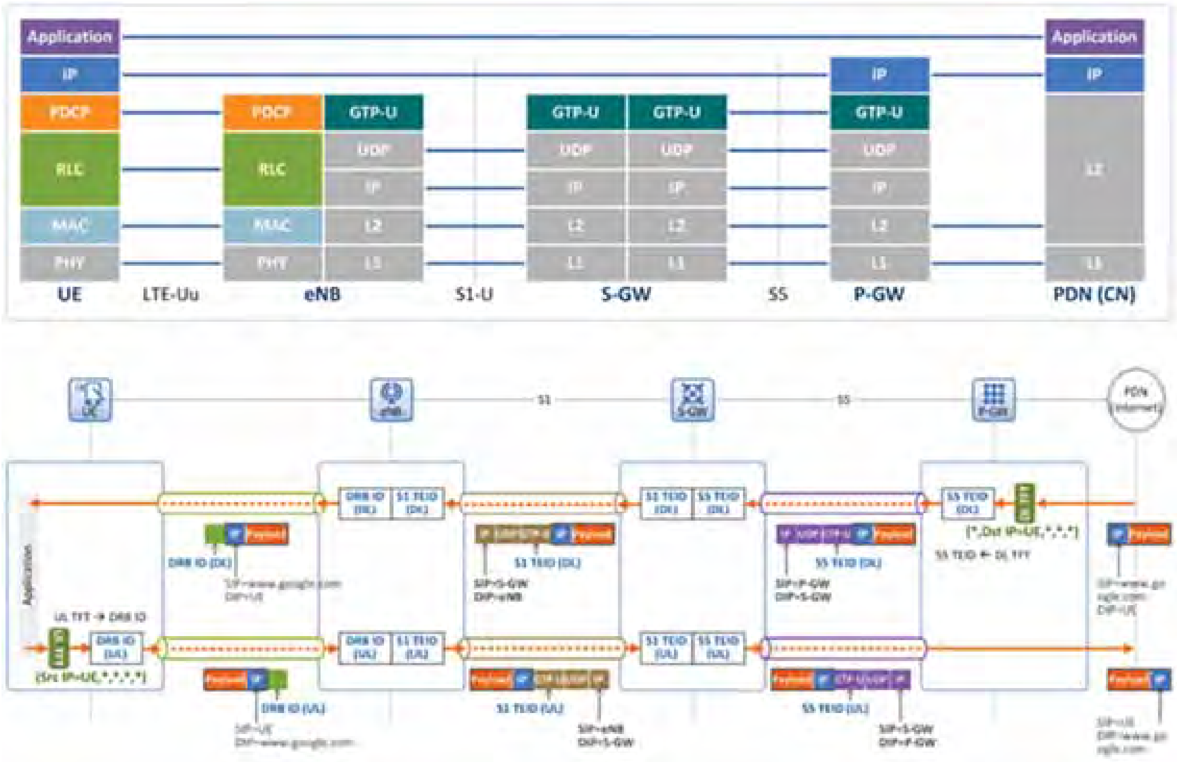


Figure 26. Tunnels between P-GW, S-GW, and eNodeB (eNB)

222. As shown in Figure 26, a tunnel is created between a P-GW and the S-GW

a. The S1-U interface is a tunnel between the eNB and S-GW. The tunnel is created with IP packets within UDP and GTP-U protocol from one IP Address to another IP Address.

b. The SS interface that connects the PDN-GW with the S-GW uses the SS interface, and a similar tunnel between them is created.

c. Once the IP and payload (IP datagram) or IP packet arrives to the P-GW it is decapsulated and sent over the internet now with the home address that is recognized by that P-GW.

d. For the Internet, the UE is right behind the P-GW. Hence a public IP address could be assigned to a UE. Alternatively, a Private IP based on NAT (Network

Address Translation) could be assigned to a UE if a private IP Address was assigned to the PDN-GW network (or P-GW element).

223. Therefore, a Foreign Agent is satisfied by a Target eNodeB.

4. Element 4 Discussion

Element 4	BASIC OPINION
a ghost-foreign agent that advertises messages to one of the mobile nodes indicating presence of the ghost-foreign agent on behalf of one of the foreign agents when the mobile node is located in a geographical area Where the foreign agent is not physically present; and	A Ghost Foreign Agent is an eNodeB advertising neighbor nodes.

224. This element is satisfied by the X2 and S1-AP handover, as the eNODEB uses the RRCReconfigirationMessage to broadcast the Target ENodeB's or Target ENodeB as shown in Figure 22 and Figure 27, and the list of CellsToAddModList contains the list of neighbor nodes to monitor by the mobile node.

225. As shown in the following Figure 27, an **RRCConnectionReconfiguration** message is depicted with the list of Cellular networks to measure. This message also functions as a Ghost Foreign Agent Advertising neighbor nodes.

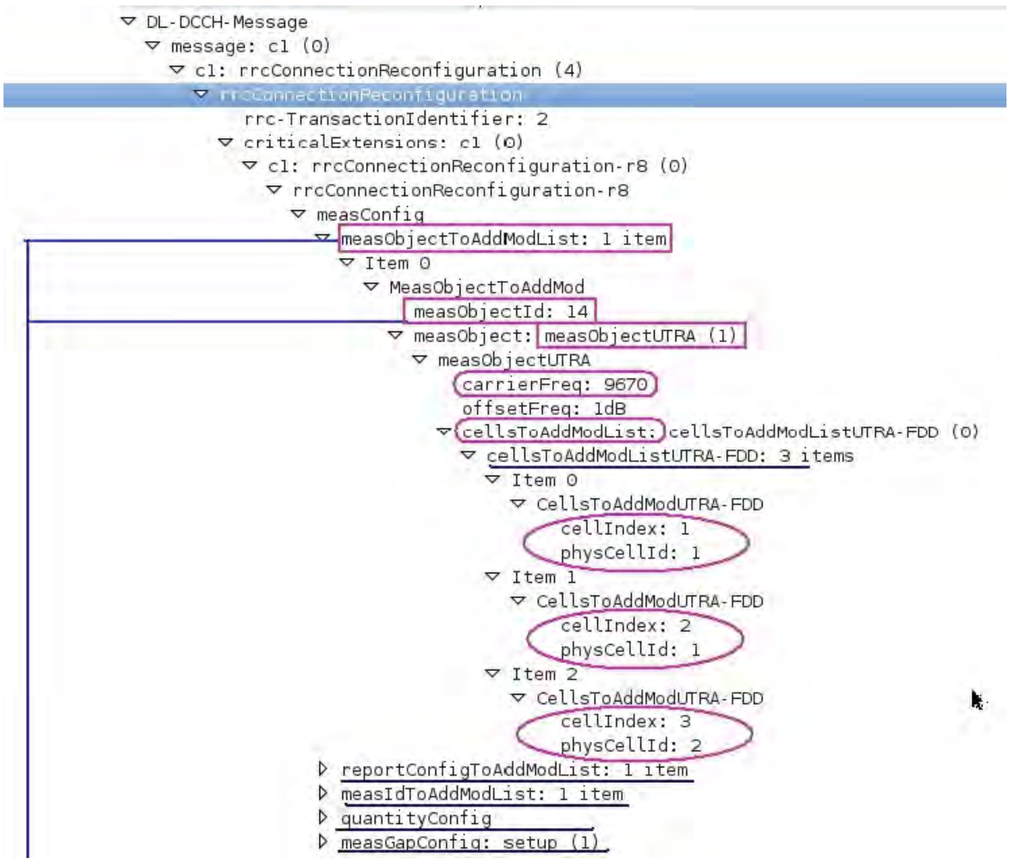


Figure 27. Format of RRCConnectionReconfiguration

226. Additionally, the System Information Block 4 (SIB4) provides a list of neighbor cells as shown below:

Information Elements		
Intra-Frequency Neighbour Cell List (1 to 16 instances)	Intra-Frequency Neighbour Cell Information	Physical Cell Identity
		Qoffset
Intra-Frequency Black Cell List (1 to 16 instances)	Physical Cell Identity Range	Start
		Range
CSG Physical Cell Identity Range	Physical Cell Identity Range	Start
		Range

LTE SIB-4

Figure 28. SIB4 - System Information Block 4

227. Support for SIB4 is required for CAT-M1 devices (IOT) in LTE (Reqs_LTE_3GPP_Band13_NetworkAccess_Feb2019, pg. 158).[49]

- Cat-M1 devices shall support the bandwidth-reduced (BR) version of System Information Blocks (SIBs), including SIB1, SIB2, SIB3, SIB4, SIB5, SIB8, SIB14, and SIB16, and shall support system information acquisition and modification, per Release 13 version of 3GPP TS 36.331.

228. The same specification discusses that TS 36.331 is followed and complied for measurement objects and measurement reports which include:

6.3.5.3 Intra-frequency measurement object

The UE reports all intra-frequency neighbouring cells i.e. not just the ones included in this IE. This IE specifies information applicable for specific intra-frequency neighbouring cells. The IE may also specify information applicable for all intra-frequency neighbouring cells (FFS).

Name	Need	Multi	Type/ reference	Semantics description	Ver
Cells to remove	OP	1..n			
>Cell index	FFS			It is FFS if a short index is used to refer to a cell (as in UTRA)	
Cells to modify	MP	1..n		It is FFS if other information may be provided	
>Cell index	FFS				
>Cell individual offset	OP				
Cells to add	MP	1..n		It is FFS if other information may be provided	
>Cell index	FFS				
>Cell individual offset	OP				

6.3.5.4 Intra-frequency measurement reporting criteria

This IE specifies criteria that affect the triggering an intra-frequency measurement event. The intra-frequency measurement are labelled aN with N equal to 1, 2, ...

Event a1: Serving becomes better than absolute threshold

Event a2: Serving becomes worse than absolute threshold

Event a3: Neighbour becomes threshold better than serving

Name	Need	Multi	Type/ reference	Semantics description	Ver
Intra-frequency event list	MP	1..n			
>Event identity					
>Threshold					
>Hysterisis					
>Time to trigger					
>Maximum number of reported cells					
Reporting interval	OP			If included, the event triggers the UE to perform periodical reporting with the indicated interval	

Figure 29. Measurement Object and Measurement Report with List of Neighbor Cells to Measure.

229. These measurements are independent from X2 and S1-AP handovers.

[49] MWVZ00002000.

230. Therefore, the element of a Ghost Foreign Agent is met and satisfied by the X2 and S1-AP handover.

5. Element 5 Discussion

Element 5	Basic Opinion
Ghost-mobile node that creates replica IP messages on behalf of a mobile node, the ghost-mobile node handling signaling required to allocate resources and initiate mobility on behalf of the mobile node, the ghost-mobile node triggering signals based on a predicted physical location of such mobile node or distance with relation to the at least one foreign agent.	**ELEMENT SATISFIED WITH HANDOVER REQUEST AND THIS CONDITION IS ALSO SATISFIED.**

231. According to Table 1, the ghost mobile node should be interpreted as "a node, or a virtual node, that can operate on behalf of the mobile node and that is capable of registering with a foreign agent and allocating resources for the mobile node before the mobile node arrives in the physical area covered by the foreign agent."

232. In this event, the eNodeB acts as a ghost mobile and acts on behalf of the mobile node registering in advance tunneling resources and all required allocations for the mobile node before the mobile node arrives to the physical area covered by the foreign agent.

233. As discussed before, a coverage area depends on multiple factors and is basically defined by the eNodeB itself. The eNodeB determines where its coverage area ends, and the coverage area of an adjacent eNodeB begins.

234. Hence, it is ghost mobile node that acts on behalf of the mobile node and, sends a replicate IP message before entering the coverage area of a Target eNodeB.

235. The coverage area should not be defined by just a fixed area of signal strength. The proper coverage area on LTE is not found where the signal strength is less than X dBm, but

rather is defined due to the hard handover decisions driven by the LTE network nodes. Coverage area depends on the parameters that the eNodeB defines and is dynamically defined and optimized by Verizon's LTE network. Further, RF signal strength is not a constant, it varies a few or more dBs per second, per day, per noise levels among others.

236. The LTE network employs hard handovers. As a result, a UE can never be within the coverage area of a Target eNodeB until the UE receives the Handover Command from the Source eNodeB.

237. Hence for all these reasons Element 5 is satisfied and Claim 1 is infringed by Verizon when it deploys LTE conforming to the 3GPP standard.

B. Discussion of Claim 4 of the '417 Patent

238. In Claim 4, A Ghost Mobile Node creates a replica message as a replica message or copies contents as part of the registration message.

239. This occurs with the HANDOVER REQUEST both in S1AP and X2 handovers, as the elements for example as Security Capabilities and parameters are copied from the Serving

eNODEB (Ghost Mobile Node) to the Target eNodeB.

9.1.1.1 HANDOVER REQUEST

This message is sent by the source eNB to the target eNB to request the preparation of resources for a handover.

Direction: source eNB → target eNB.

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.2.13		YES	reject
Old eNB UE X2AP ID	M		eNB UE X2AP ID 9.2.24	Allocated at the source eNB	YES	reject
Cause	M		9.2.6		YES	ignore
Target Cell ID	M		ECGI 9.2.14		YES	reject
GUMMEI	M		9.2.16		YES	reject
UE Context Information		1			YES	reject
>MME UE S1AP ID	M		INTEGER ($0..2^{32}-1$)	MME UE S1AP ID allocated at the MME	–	–
>UE Security Capabilities	M		9.2.29		–	–

240. During the HANDOVER REQUEST the Security Capabilities, UE Context Information, UE Network Capabilities are copied from the UE to the Target eNodeB.

Element 1	Basic Opinion
Ghost-mobile node that creates replica IP messages on behalf of a mobile node, the ghost-mobile node handling signaling required to allocate resources and initiate mobility on behalf of the mobile node, the ghost-mobile node triggering signals based on a predicted physical location of such mobile node or distance with relation to the at least one foreign agent.	**These elements are satisfied** **Verizon infringes CLAIM 4 of the ’417 Patent.**

C. Discussion of Claim 7 of the ’417 Patent

241. This is a method claim with a Preamble as follows:

Preamble	Basic Opinion
Preamble: A method, in a mobile node, for speeding handover, comprising the steps of:	This element is satisfied.

242. The UE contains software and elements in the stack that implement the X2 and S1-AP handover. These handover processes speed up LTE's response and improves user experience, especially for VoLTE (Voice over LTE Systems).

1. Discussion Element 1

Element 1	Basic Opinion
updating, in a mobile node, a location in a ghost mobile node;	**The elements of this element are satisfied by Verizon**

243. This process of copying the location of a mobile node into the Ghost Mobile Node, or serving eNodeB.

244. The location information or position is copied over to the eNodeB by Verizon. This is done by the Measurement Report and it contains device's location except when battery is less than 10% and few other exceptions. (MWVZ00001987-MWVZ00001988.)

245. Therefore, Element 1 is satisfied.

1.3.2.24.3.4 LocationInfo for measurement report VZ_REQ_LTEB13NAC_38232

The device shall set *LocationInfo* in measurement report (immediate reporting) if *includeLocationInfo* is configured in the corresponding *reportConfig* for the *measId* as stated in section 5.5.5, 6.2.2 in the release 10 version of 3GPP TS 3GPP TS 36.331: *Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) Protocol Specification.*

2. Discussion Element 2

Element 2	Basic Opinion
determining a distance, in the ghost mobile node in communication with the mobile node, to a closest foreign agent with which the mobile node can complete a handover;	**This element is satisfied by X2 and S1AP handover**

246. As the phone travels and UE's location is mapped to a measurement report of RSRQ (Signal strength), a distance (and location of the UE) is known through triangulation.

247. Distance is also computed by the E911 requirements[50] of the phone, and approximately known by the MME. The measured RSRQ values correspond to the distance of a UE to a Foreign Agent or eNodeB.

248. By solving the inequality with A3, A2, A1 events, or other events, the closest distance is computed, indirectly. In fact, Minimized Drive Test (MDT) maps location to signal strength.

249. For cases in which, a Femto-cell is used this association is even more evident, including SON.

250. For the femtocell cases, Verizon requires "Proximity Indication" to CSG Cells. CSG stands for Closed Subscriber Group (CSG).[51]

> **1.4.1.18.4.4 RRC AND RRM SUPPORT FOR CSG CELLS - Proximity Indication** VZ_REQ_LTEB13NAC_6477
>
> The device shall send a ProximityIndication message to the network whenever it detects or leaves the presence of CSG or hybrid cells if configured by the network to do so per section 5.3.14 of 3GPP TS 36.331: *Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification* and section 10.5.1.2 of
>
> Page **193** of **250**
>
> 3GPP TS 36.300: *Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2.*

3. Discussion Element 3

Element 3	BASIC OPINION
submitting on behalf of the mobile node, from the ghost mobile node, a registration to the foreign agent to which the mobile node is going to complete the handover; and	**THIS ELEMENTI IS MET BY VERIZON'S X2 HANDOVER AND CSG CELLS / ENODEBS.**

50 MWV00002178.

51 Reqs_LTE_3GPP_Band13_NetworkAccess_Feb2019, pg 193 and 194. MWVZ00002035 and MWVZ00002036.

251. The Proximity Indicator is a message that determines and implements Element 2 of the Claim and then Element 3 follows as part of the Handover process and S1AP handover. This is established in TS 36.331 as part of CSG Cells. (Please see Figure 30 below.)

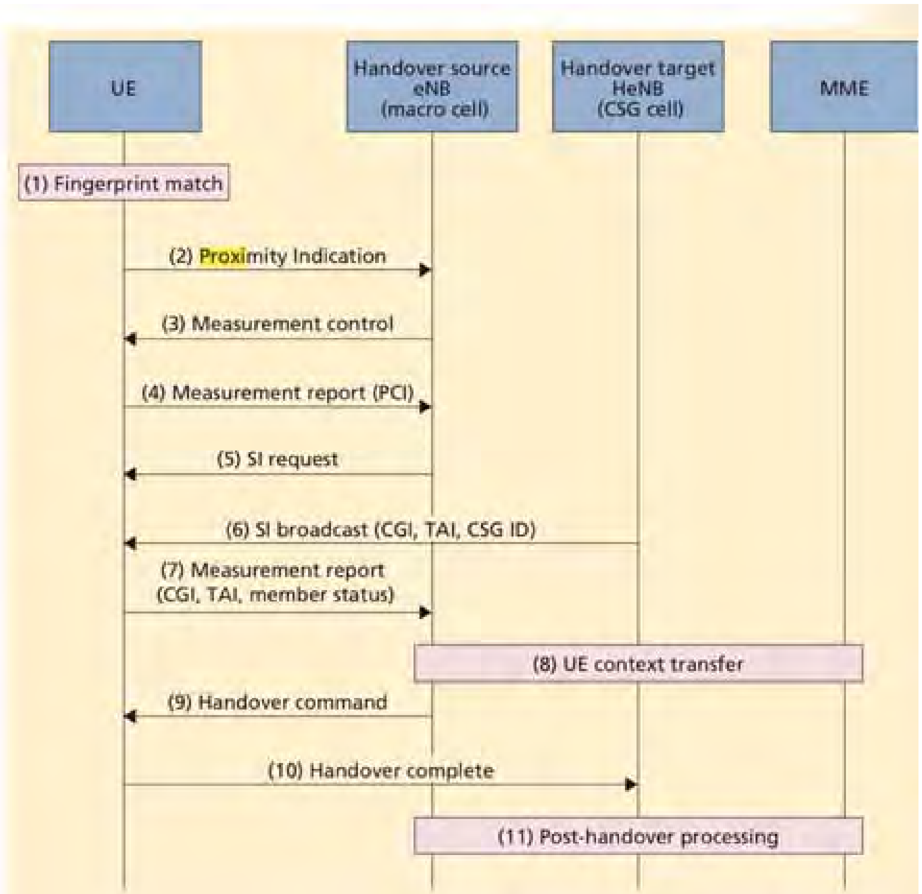


Figure 30. Proximity Indicator and S1 AP Handover.[52]

252. In a similar fashion as a neighbor eNodeB is used, the Proximity Indicator, determines the closet distance to the eNodeB.

253. Therefore Element 3 is met.

4. Discussion Element 4

Element 4	BASIC OPINION
upon completing the handover, updating a registration in the mobile node.	**ELEMENT OF THIS CLAIM IS MET**

[52] N. Iwamura, et.al. Further Enhancements of LTE -LTE Release 9, NTT DOCOMO, 2010.

254. As shown in Figure 30, upon completion of the handover a registration is updated in the mobile node. (*See also* Figure 24.)

255. Hence, Element 4 of Claim 7 is satisfied and Claim 7 is infringed.

XVIII. Conclusions

256. For the reasons detailed above, it is my opinion that the Verizon Emulator meets or includes every element of limitation of claims 1, 3, and 4 of the '330 Patent. For the reasons detailed above, it is my opinion that the Verizon LTE Network meets or includes every element or limitation of claim 1, 4, and 7 of the '417 Patent and, therefore, it is my opinion that the Verizon LTE Network infringes claims 1, 4, and 7 of the '417 Patent.

Date: June 20, 2019

By: ______________________

Dr. Sukumaran Nair

EXHIBIT A

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2016 - Present:	*Director,* AT&T Center for Virtualization
2015 - Present:	*University Distinguished Professor*
2008 -2017:	*Professor* and *Chair*, Dept. of Computer Science and Engineering, Southern Methodist University.
2005 - Present:	*Professor*, Dept. of Computer Science and Engineering, Southern Methodist University.
1996 - 2005:	*Associate Professor*, Dept. of Computer Science and Engineering, Southern Methodist University.
1998 Jan. - Jun.	*On Sabbatical* Computer Engineering Research Centre, University of Texas at Austin.
1990 - 1996:	*Assistant Professor*, Dept. of Computer Science and Engineering, Southern Methodist University.
1986 - 1990:	*Research Assistant*, Coordinated Science Laboratory, University of Illinois, Urbana.
1984 - 1985:	*Engineer*, Indian Space Research Organization, Trivandrum, India.

Research Interests:

Software Centric Telecom Systems, Cloud and Network Security, High Assurance Systems

Awards and Honors:

- Selected to serve on the Executive Board of Episcopal School of Dallas (ESD), 2018
- Selected to Dallas 500, D-CEO magazine, 2017
- D-CEO magazine CIO/CTO Awards, Outstanding Tech Advocate, 2017
- University Distinguished Professor 2015
- IBM Faculty Award 2014
- SMU Distinguished University Citizen Award, May 2014
- Ford Research Fellow, 2013
- Distinguished Engineer of the Year, MEANT 2013
- Faculty Affiliate, ***eCenter***, SMU, Dallas, 2001
- Outstanding Graduate Faculty Award, 1995, 1996, 2004, 2009
- J. Lindsay Embrey Trustee Professorship in Engineering, May 1995.
- State First Rank, Electronics and Telecommunication Engineering, University of Kerala, India, 1984.

Relevant Research Grants and Proposals:

- S. Nair (PI), Study of Network Restoration Control Strategies for Self-Healing Hybrid Ring Network Topologies Utilizing Digital Cross-Connect Systems, *Alcatel Network Systems (ANS)* , Feb. 1993 - Dec. 1994, **$58,381**.
- S. Nair (PI), Distributed Object-Oriented Databases, *Texas National Research Laboratory Consortium (TNRLC)* , Feb. 1993 - Dec. 1994, **$60,381**.
- S. Nair (PI), Spectral-Based Numerical Methods for Digital Logic Synthesis, *National Science Foundation (NSF-RIA)*, Jul. 1994 - Jun. 1997, **$100,000**.
- S. Nair (PI), Distributed Computing for Personal Communication Systems (PCS), *Bell Northern Research (BNR) Inc.*, Aug. 1994 - Jan. 1995, **$60,000**.
- S. Nair (PI), Reliable Distributed Computing for Personal Communication Systems (PCS), *Bell Northern Research (BNR) Inc.*, Feb. 1995 - Dec. 1995, **$110,000**.
- S. Nair (Co PI with J. Kennington), Design of Highly Survivable SONET Networks, *Texas Advanced Technology Program*, Jan. 1996 - Dec. 1997, **$290,592**.
- S. Nair (PI), Distributed Wireless Networks, *Nortel Inc.*, Jan. 1997 - Dec. 1997, **$60,000**.
- S. Nair (PI), Performance Evaluation of SBB Switches Using OPNET Simulations, *DSC Inc.*, Jan. 1998 - Dec. 1998, **$72,000**.
- S. Nair (PI), Line Encoding Schemes for Burst Switched Optical Routers, *Alcatel Inc.*, Jan. 1999 – Dec.1999, **$25,000**.
- S. Nair (CoPI with J. Abraham), Validating Secure Network Protocols for Electronic Commerce, *Texas Advanced Technology Program*, Jan. 2000 - Aug. 2002, **$272,000**.
- S. Nair (PI), Restoration of Metro-Ethernet, *Alcatel Inc.*, Mar. 2003 - Dec. 2003, **$30,000**.
- S. Nair (PI), Restoration and Security of Metro-Ethernet, *Alcatel Inc.*, Feb. 2004 - Dec. 2004, **$50,000**.
- S. Nair (CoPI with M. Marchetti), Systems Security Engineering, Capability Maturity Models, *Electronic Warfare Associates (EWA/ IIT) Inc.*, Sep. 2004 - May. 2005, **$74,000**.
- S. Nair (PI), Traffic Engineering and Security of Metro-Ethernet, *Alcatel Inc.*, Dec. 2004 - Dec. 2005, **$60,000**.
- S. Nair (PI), Nano-Security Initiative with a Focus on Nano-Sensors, National Institute of Standards and Technology (NIST), Oct. 2005 - Oct. 2006, **$60,000**.
- S. Nair (PI), Multi-casting strategies in Metro-Ethernet, *Alcatel Inc.*, Dec. 2005 - Dec. 2006, **$50,000**.
- S. Nair (PI), End-To-End Diagnostics of Multicasting IPTV, *Alcatel Inc.*, Feb. 2007 - Dec. 2007, **$50,000**.
- S. Nair (CoPI with J. Tian, H. El-Rewini), IUCRC Planning Proposal: SMU Research Site Proposal to Join Embedded Systems IUCRC, National Science Foundation, Mar. 2007-Feb. 2008, **$10,000**
- S. Nair, NSF I/UCRC Industry Affiliates (T-Systems, Hall Financials, GlobeRanger, Prismstream), Oct. 2008-Oct 2009, **$130,000**.
- S. Nair (CoPI with M. Thornton and S. Szygenda), Large System Design and Axiomatic Approach, Office of Naval Research (ONR), April 2009 – Dec. 2009, **$250,000**
- S. Nair (PI) (M. Thornton - CoPI), Information Assurance Scholarship Program Proposal, NSA/DHS, Jun. 2009-May 2010, **$45,000.**
- S. Nair (PI) Key Distribution in Wireless Sensor Networks without PKI, Revere Security Inc. Jan. 2010-Dec. 2010**, $30,000.**
- S. Nair (PI) (M. Thornton, T. Manikas - CoPIs), Information Assurance Scholarship Program, NSA/DHS, Aug. 2010-July 2011, **$439,375.**

- S. Nair (PI) (M. Thornton - CoPI), Design, Implementation and Evaluation of Efficient In-Line Memory Encryption Algorithms, Lockheed Martin Inc., Aug. 2010-Dec. 2010, **$25,000.**
- S. Nair (PI) Cyber Range for Assurance Testing, Rockwell Collins Inc. Jan. 2011 – March 2011, **$12,000.**
- S. Nair (PI) (M. Thornton, T. Manikas - CoPIs), Information Assurance Scholarship Program, NSA/DHS, Aug. 2010-July 2011, **$404,478.**
- S. Nair (PI) (M. Thornton, J. Dworak - CoPIs), Hardware Trust Establishment and Extension, Lockheed Martin Inc., Aug. 2011-Jul. 2012, **$106,000.**
- S. Nair (CoPI with J. Tian, L. Huang), MRI Consortium: Development of Instrumentation for Measuring the Dependability and Quality of Cloud Computing Systems, National Science Foundation, Sept. 2011- Aug. 2014, **$487,352**
- S. Nair (PI) (M. Thornton, T. Manikas - CoPIs), Information Assurance Scholarship Program Proposal, NSA/DHS, Aug. 2010-July 2011, **$66,813.**
- S. Nair (CoPI with F. Chang, M. Thornton), Formal Cyber Mission Planning and Analysis: Security Properties, Raytheon Inc., Dec. 2013 – Apr. 2015, **$350,000**
- S. Nair (PI) (M. Thornton, T. Manikas - CoPIs), Information Assurance Scholarship Program Proposal, NSA/DHS, Sept. 2013-Sept. 2014, **$66,813.**
- S. Nair (PI) (T. Manikas, M. Thornton - CoPIs), Information Assurance Scholarship Program Proposal, NSA/DHS, Sept. 2014-Sept. 2015, **$66,000.**
- S. Nair (PI), Evaluation of AT&T SDN Architecture, *AT&T Inc.*, Mar. 2015 - Feb. 2016, **$115,000**.
- S. Nair (PI), Evaluation of API Platforms for Virtualized Network Functions, AT&T Inc., Jun. 2016 - Jun. 2017, **$160,000**.
- S. Nair (PI), AT&T Center for Virtualization, AT&T Inc., Aug. 2016 (Permanent Endowment), Aug. 2016, **$2,500,000**.
- S. Nair (PI) (T. Manikas, CoPI), Information Assurance Scholarship Program Proposal, NSA/DHS, Sept. 2016-Sept. 2017, **$72,000.**
- S. Nair (PI), Automated Decision Support System for Cloud Deployment, Google Inc., Dec. 2017 - Nov. 2019, **$290,000**.
- S. Nair (PI), A disaggregated hardware and software architecture for programmable network infrastructure to support scalable security, reliability and QoS, SPAWAR, Feb. 2018 - Jan. 2019, **$95,000**.
- S. Nair (PI), Affiliate Membership with SMU AT&T Center for Virtualization, Ericsson, Raytheon, Fujitsu, CyrusOne., Jan. 2018 – Dec. 31. 2019, **$225,000**.
- S. Nair (CoPI with E. Larson), Human Performance Optimization using Biometric Indices: Integration for the Next Generation Technology Demonstrator (NGTD), L3 Technologies, Inc., Sep. 2018 – Aug. 2019, **$200,000.**

Publications:

- V. S. S. Nair and J. A. Abraham. Average checksum codes for fault-tolerant matrix operations on processor arrays. *Proceedings of the International Conference on Supercomputing*, 3:284-290, May, 1987.
- V. S. S. Nair and J. A. Abraham. General linear codes for fault-tolerant matrix operations on processor arrays. *Proceedings of the18thIEEE International Symposium on Fault-Tolerant Computing*, pages 180-185, Jun. 1988.
- P. Banerjee, J. T. Rahmeh, C. B. Stunkel, V. S. S. Nair, K. Roy, and J. A. Abraham. An evaluation of system-level fault tolerance on the Intel hypercube multiprocessor.

Proceedings of the 18th IEEE International Symposium on Fault-Tolerant Computing, pages 362-367, Jun. 1988.

- V. S. S. Nair and J. A. Abraham. A model for the analysis of fault-tolerant signal processing architectures. *Proceedings of SPIE Advanced Algorithms and Architectures for Signal Processing Conference*, pages 246-257, Aug. 1988.
- V. S. S. Nair and J. A. Abraham. A model for the analysis, design and comparison of fault-tolerant WSI architectures. *Proceedings of IFIP Workshop on Wafer Scale Integration*, pages 99-108, June 1989.
- V. S. S. Nair and J. A. Abraham. Real number codes for fault-tolerant matrix operations on processor arrays. *IEEE Transactions on Computers*, pages 426-435, Apr. 1990.
- V. S. S. Nair and J. A. Abraham. Hierarchical design and analysis of fault-tolerant multiprocessor systems using concurrent error detection. *Proceedings of the 20th IEEE International Symposium on Fault-Tolerant Computing*, pages 130-137, Jun. 1990.
- V. S. S. Nair and J. A. Abraham. A new probabilistic model for the analysis of fault-tolerant systems using concurrent error detection. *Proceedings of SPIE Advanced Algorithms and Architectures for Signal Processing Conference*, Jul. 1990.
- P. Banerjee, J. Rahmeh, C. Stunkel, V. S. S. Nair, K. Roy, and J. A. Abraham. Algorithm-based fault tolerance on a hypercube multiprocessor. *IEEE Transactions on Computers*, pages 1132-1145, Sep. 1990.
- V. S. S. Nair, Y. V. Hoskote, and J. A. Abraham. Probabilistic evaluation of on-line checks in fault-tolerant multiprocessor systems. *IEEE Transactions on Computers*, 41:532-541, May, 1992.
- B. Kapoor and V. S. S. Nair. Heuristics for Shannon decomposition in area-efficient realization of fully robust path delay fault testable digital logic. *Proceedings of IEEE International Workshop on Logic Synthesis (IWLS)*, pages 4c1-4c8, May 1993.
- M. A. Thornton and V. S. S. Nair. A numerical method for Reed-Muller circuit synthesis. *Proceedings of IFIP Workshop on Applications of the Reed-Muller Expansion in Circuit Design*, pages 69-74, Sep. 1993.
- M. A. Thornton and V. S. S. Nair. An iterative combinational logic synthesis technique using spectral information. *Proceedings of IEEE European Design Automation Conference (EURO-DAC)*, pages 358-363, Sep. 1993.
- S. Krishna, T. Diamond, and V. S. S. Nair. Hierarchical object oriented approach to fault tolerance in distributed systems. *Proceedings of IEEE International Symposium on Software Reliability Engineering*, pages 168-177, Nov. 1993.
- C. Erbas, M. Tanik, and V. S. S. Nair. Storage schemes for parallel memory systems: An approach based on circulant matrices. *Proceedings of IEEE Symposium on Parallel and Distributed Processing (SPDP)*, pages 92-99, Dec. 1993.
- R. Rowell and V. S. S. Nair. Secondary storage error correction utilizing inherent redundancy of stored data. *Proceedings of IFIP Working Conference on Dependable Computing for Critical Applications (DCCA)*, Jan. 1994.
- B. Kapoor and V. S. S. Nair. Area, performance, and sensitizable paths. *Proceedings of 4th IEEE Great Lake Symposium on VLSI*, pages 222-227, Mar. 1994.
- M. A. Thornton and V. S. S. Nair. Behavioral to structural translation in ESOP form. *Proceedings of IEEE International Verilog HDL Conference*, pages 58-62, Mar. 1994 (Best Paper Award).
- R. Rowell and V. S. S. Nair. SELAC - statistical error location and correction in secondary memory systems. *Journal of Micro Computer Applications*, 17:255-271, Jun. 1994.
- V. S. S. Nair and S. Venkatesan. Algorithm-based fault tolerance for non-computationally intensive applications. *Proceedings of SPIE Advanced Algorithms and Architectures for Signal Processing Conference*, pages 751-759, Jul. 1994.

- B. Kapoor and V. S. S. Nair. Computing exact path delay fault coverage using OBDDs. *Proceedings of IEEE Midwest Symposium on Circuit and Systems*, Aug. 1994.
- B. Kapoor and V. S. S. Nair. An efficient tree-based algorithm for computing path delay fault coverage. *Proceedings of IEEE International ASIC Conference*, pages 417-420, Sep. 1994.
- M. A. Thornton and V. S. S. Nair. Efficient spectral coefficient calculation using circuit output probabilities. *Digital Signal Processing: A Review Journal*, pages 245-254, Oct. 1994.
- C. Erbas, M. Tanik, and V. S. S. Nair. Parallel memory allocation and data alignment in SIMD machines. *Journal on Parallel Algorithms and Applications*, 4:139-151, Dec. 1994.
- M. Thornton and V. S. S. Nair. Parity function detection and realization using a small set of spectral coefficients. *Proceedings of IEEE/ACM International Workshop on Logic Synthesis (IWLS)*, pages 8.39 - 8.47, May 1995.
- H. Kim and V. S. S. Nair. Application layer software fault tolerance for distributed object-oriented systems. *IEEE International Conference on Computer Software and Applications (COMPSAC-95)*, pages 235-241, Aug. 1995.
- M. Thornton and V. S. S. Nair. Fast Reed-Muller spectrum computation using output probabilities. *IFIP WG 10.5 Workshop on Applications of Reed-Muller Expansion in Circuit Design*, pages 281 - 287, Aug. 1995.
- C. F. Salviano and V. S. S. Nair. One-for-many: A design pattern for a piecemeal programming language extension through one-to-many translation. *Proceedings of Second Annual Conference on the Pattern Languages of Programs*, pages 1-9, Sep. 1995.
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- M. Thornton and V. S. S. Nair. Efficient calculation of spectral coefficients and their applications. *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, 14:1328-1341, Nov. 1995.
- V. S. S. Nair, K. Indiradevi, and J. A. Abraham. Formal checking of reliable user interfaces. *Proceedings of IEEE International Conference on Fault-Tolerant Systems*, pages 17-25, Dec. 1995.
- M. Thornton and V. S. S. Nair. BDD-based spectral approach for Reed-Muller circuit realization. *IEE Proceedings - Computers and Digital Techniques*, 143:145-150, Mar. 1996.
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- V. S. S. Nair, H. Kim, N. Krishnamurthy, and J. A. Abraham. Design and evaluation of automated high-level checks for signal processing applications. *Proceedings of SPIE Advanced Algorithms and Architectures for Signal Processing Conference*, pages 292-301, Aug. 1996.
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- H. C. Cankaya and V. S. S. Nair. Reliability and availability evaluation of self-healing SONET mesh networks. In *IEEE Proceedings of GLOBECOM'97*, volume 1, pages 252-256. IEEE Com. Soc., 1997.
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- H. Kim and V. S. S. Nair. Software fault tolerance for distributed object-based computing. *The Journal of Systems and Software*, Vol. 39, No.2, pp. 103-117, Nov. 1997.
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- Z. Alkhalifa, V. S. S. Nair, N. Krishnamurthy, and J. A. Abraham. Design and evaluation of system-level checks for on-line error detection in real-time systems. *IEEE Transactions on Parallel and Distributed Systems*, June 1999.
- Z. Alkhalifa and V. S. S. Nair. Linear codes for end to end cell loss recovery in VBR video transmission over ATM networks. *IEEE International Conference on ATM '99*, June 1999.

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- K. Indiradevi, V. S. S. Nair, and J. A. Abraham. A meta-authentication framework for secure authentication protocols. *Infrastructure for e-Business, e-Education, and e-Science on the Internet, SSGRR-2001, Italy*, Aug. 2001.
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- M. Stephens and S. Nair, Internet Distributed Computing for e-Business, *Proceedings of the Seventh International Conference on Electronic Commerce Research*, pp. 221 – 233, Jun. 2004.
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- M. Padmaraj; S. Nair; M. Marchetti; G. Chiruvolu; M. Ali; A. Ge; "Metro Ethernet traffic engineering based on optimal multiple spanning trees", Wireless and Optical Communications Networks, 2005. WOCN 2005. Second IFIP International Conference on 6-8 March 2005 Page(s):568 - 572
- G. Deprez, M. Padmaraj, S. Nair, "Net Planner: A Capacity Allocation Tool", Telecommunications, 2005. ConTEL 2005. Proceedings of the 8th International Conference on Volume 1, June 15-17, 2005 Page(s):147 - 154
- M. Padmaraj, S. Nair, M. Marchetti, G. Chiruvolu, and M. Ali, "Simulation of recovery scheme for Metro Ethernet", In Proceedings of OPNETWORKS'05, August 2005
- M. Ali, , G. Chiruvolu, M. Padmaraj, S. Nair, and M. Marchetti "Augmented Hose Model for Metro Ethernet", In proceedings of IEEE ICON, November 2005
- G. Deprez, M. Padmaraj, S. Nair, "Restoration Protocol for Heterogeneous Networks", IEEE AICCSA, March 2006
- M. Ali, , G. Chiruvolu, A. Ge, M. Padmaraj, S. Nair, and M. Marchetti "Differentiated Survivability in Ethernet-Based MAN/WAN", IEEE AICCSA, March 2006

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- M. Padmaraj, S. Nair, M. Marchetti, G. Chiruvolu, and M. Ali, "Distributed Fast Failure Recovery Scheme for Metro Ethernet", IEEE ICN, April 2006
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- S. Abu-Nimeh, S. Nair, "Bypassing Security Toolbars via DNS Poisoning", IEEE Global Communications Conference (GLOBECOM), Nov. 30- Dec. 4, 2008, Pages 1-6.
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- T. Morris, S. Nair, "Encryption Key Protection for Private Computing on Public Platforms", Proceedings of the Seventh Annual IEEE International Conference on Pervasive Computing and Communications (Percom 2009). Galveston, TX, USA. 9-13 March 2009.
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- S. Abu-Nimeh, S. Nair, "Circumventing Security Toolbars and Phishing Filters via Rogue Wireless Access Points", The Journal of Wireless Communications and Mobile Computing, Wiley InterScience Journals, Vol. 9999, Jun. 2009.
- T. Morris, S. Nair, "Key Protection for Private Computing on Public Platforms", International Journal of Computer Science and Security (IJCSS). Volume 3, Issue 5. Pages 371-383. CSC Journals. Nov. 2009.
- L. Spenner, P. Krier, M. Thornton, S. Nair, S. A. Szygenda, and T. Manikas, Large System Decomposition and Simulation Methodology Using Axiomatic Analysis, Proc. of *IEEE International Systems Conference*, April 5-8, 2010
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- L. Spenner, P. Krier, M. Thornton, S. Nair, S. A. Szygenda, and T. Manikas, An Axiomatic Analysis Approach for Large-Scale Disaster-Tolerant Systems Modeling, Proc. Of the *Int. Conf. on Computing, Communications and Control Technologies*, April 6-9, 2010.
- P. Krier, S. N. P. Seshabhattar, D. W. Engels, and S. Nair, "Cloaking rfid tags," in 8th Annual IEEE Consumer Communications and Networking Conference IEEE CCNC 2011, 2011.
- S. N. P. Seshabhattar, P. N. Yenigalla, P. Krier, and D. W. Engels, "Hummingbird key establishment protocol for low-power zigbee," in 8th Annual IEEE Consumer Communications and Networking Conference IEEE CCNC 2011, 2011.
- T. Manikas, L. Spenner, P. Krier, M. Thornton, S. Nair, and S. Szygenda, "An axiomatic analysis approach for large-scale disaster-tolerant systems modeling," in Int. Multi-Conf on Complexity, Informatics, and Cybernetics (IMCIC'10), 2010

- B. Alqudah, S. Nair, "Toward Multi-Service Electronic Medical Records Structure", SDPS-2010, Jun. 2010
- S. Rafiqi, S. Nair, Complete Healthcare Information Delivery System (C-HIDS), SDPS-2010, Jun. 2010
- M. Malaika, S. Nair, F. Coyle "Application Security Automation for Cloud Computing", , 2nd International ICST Conference on Cloud Computing, Barcelona, Spain October, 2010
- P. Krier, S. Seshabhattar, J. Pereira, D. Engels, and S. Nair, "Lightweight key agreement with key chaining," in Mobile Adhoc and Sensor Systems (MASS), 2010 IEEE 7th International Conference on. IEEE, 2010, pp. 594–599.
- S. Papa, W. Casper and S. Nair, "Placement of Trust Anchors in Embedded Computer Systems" IEEE Int. Symposium on Hardware-Oriented Security and Trust, Jun. 2011, pp. 111-116.
- S. Nair, S. Abraham, O. Al-Ibrahim, "Security Fusion: A New Security Architecture for Resource-Constrained Environments", Proceedings of the 6th USENIX conference on Hot topics in security, HotSec'11, 2011
- T. Manikas, L. Spenner, P. Krier, M. Thornton, S. Nair, and S. Szygenda, "An axiomatic analysis approach for large-scale disaster-tolerant systems modeling," Journal of Systemics, Cybernetics and Informatics, 2011
- S. Nair, S. Abraham, O. Al Ibrahim, "Security Architecture For Infrastructure Protection", in IEEE proceedings of the 7th International Wireless Communications and Mobile Computing Conference (IEEE IWCMC), Istanbul, Turkey, 2011.
- O. Al Ibrahim, S. Nair, "Cyber-Physical Security Using System-Level PUFs" , in IEEE proceedings of the 7th International Wireless Communications and Mobile Computing Conference (IEEE IWCMC), Istanbul, Turkey, 2011.
- O. Al Ibrahim, S. Nair, "Security Fusion Based On State Machine Compositions", IEEE Symposium on Computational Intelligence in Cyber Security (IEEE CISC-SSCI), Paris, France, 2011
- S. Papa, W. Casper, S. Nair, Availability Based Risk Analysis for SCADA Embedded Computer Systems, Proceedings of the 2011 International Conference on Security and Management, Worldcomp'11, July 2011,CSREA Press, 541-547
- E. Cankaya, S. Nair, C. Cankaya., "Applying Error Correction Codes to Achieve Security and Dependability", Journal of Computers Standards and Interfaces, July 2012
- S. Papa, W. Casper, S. Nair, A Transfer Function based Intrusion Detection System for SCADA Systems, *IEEE International Conference on Technologies for Homeland Security (IEEE HST)*, Waltham, MA, USA, November 2012, IEEE, 93-98
- W. Casper, S. Papa, S. Nair, *Security Fusion Implementation and Optimization in SCADA Systems, IEEE International Conference on Technologies for Homeland Security (IEEE HST)*, Waltham, MA, USA, November 2012, IEEE, 620-625
- R. Al-Awadhi, S. Nair, "A joint scheme for secure and reliable communication in wireless sensor networks", *IEEE ACS 2013: International Conference on Computer Systems and Applications ({AICCSA),* May 2013.
- Eshmawi, S. Nair, "Smartphone Applications: Survey of New Vectors and Solutions", *In Proceedings of The IEEE International Conference on Computer Systems and Applications,* May, 2013
- R. Al-Awadhi, S. Nair, A Crypto-System with Embedded Error Control for Secure and Reliable Communication, *International Journal of Computer Science and Security,* Jun., 2013, pp. 48-61
- Eshmawi, S. Nair, "Feature Reduction for Optimum SMS Spam Filtering Using Domain Knowledge", *2013 International Conference on Security and Management (SAM'13), Jul. 2013.*

- O. Al Ibrahim, S. Nair, "State Machine-Based Security Fusion for Resource-Constrained Environments", IEEE Systems Journal - Special Issue on Security and Privacy in Complex Systems, Sept. 2013, pp. 430-441
- S. Rafiqi, S. Nair, E. Fernandez, "Markup Language for Cognitive and Context-Aware Adaptable User Interface", *IADIS International Conference on Applied Computing,* Oct. 2013
- Eshmawi, S. Nair, "Privacy of Smartphone Applications", *IADIS International Conference on Applied Computing,* Oct. 2013
- S. Rafiqi, S. Nair, E. Fernandez, "Affective and Cognitive UI for Enhanced Usability", *5th International Conference on Applied Human Factors and Ergonomics*, AHFE 2014 Krakow, Poland, July 2014
- Eshmawi, S. Nair, "Semi-Synthetic Data for Enhanced SMS Spam Detection", ACM International Conference on Management of Emergent Digital Eco Systems (MEDES), Sept. 2014
- M. Malaika, S. Nair, F. Coyle "N-Version Architectural Framework for Application Security Automation (NVASA)", CrossTalk, The Journal of Defense Software Engineering (DoD), Sep. 2014, 30-34
- S. Abraham, S. Nair, "Cyber Security Analytics: A stochastic model for Security Quantification using Absorbing Markov Chains", 5th International Conference on Networking and Information Technology (ICNIT 2014), Nov. 2014
- S. Abraham, S. Nair, "Predictive Cyber Security Analytics Framework: A non-homogenous Markov Model for Security Quantification", 2nd International Conference of Security, Privacy and Trust Management (SPTM 2014), Dec. 2014.
- S. Abraham, S. Nair, "Cyber Security Analytics: A stochastic model for Security Quantification using Absorbing Markov Chains", Journal of Communications, Vol. 9, No. 12, Dec. 2014
- S. Abraham and S. Nair, "A Predictive Framework for Cyber Security Analytics using Attack Graphs", International Journal of Computer Networks & Communications (IJCNC), Vol.7, No.1, January 2015
- S. Abraham and S. Nair, "Exploitability analysis using predictive cyber security framework", 2nd IEEE International Conference on Cybernetics (CYBCONF), Jun. 2015.
- S. Rafiqi, S. Nair, C. Wangwiwattana, E. Fernandez, E. Larson, J. Kim "PupilWare: Towards Pervasive Cognitive Load Measurement using Commodity Devices", ACM Proceedings of the 7th International Conference on PErvasive Technologies Related to Assistive Environments, Petra 2015, Corfu, Greece, Jul. 1-3, 2015
- S. Abraham and S. Nair, "A Novel Architecture for Predictive CyberSecurity using non-homogenous Markov Models", IEEE International Symposium on Recent Advances of Trust, Security, and Privacy in Computing and Communications, (In Conjunction with IEEE TrustCom-15), Helsinki, Finland, Aug. 2015.
- S. Rafiqi, C. Wangwiwattana, S. Nair, E. Larson, E. Fernandez, " PupilWare-M: Cognitive Load Estimation Using Unmodified Smartphone Cameras", First International Workshop on Social Sensing (SocialSens 2015), Oct. 2015.
- S. Abraham and S. Nair, "Estimating Mean Time to Compromise using non-homogenous continuous-time Markov models", 40th IEEE Annual Computer Software and Applications Conference (COMPSAC 2016), Jun. 2016
- D. Horne and S. Nair, "The Prom Problem: Fair and Privacy-Enhanced Matchmaking with Identity Linked Wishes", 2016 IEEE International Carnahan Conference on Security Technology (ICCST), Oct. 2016.
- S. Abraham and S. Nair, "Comparative Analysis and Patch Optimization using Cyber Security Analytics Framework", Journal of Defense Modeling and Simulation: Applications, Methodology, Technology, May. 2017.

- D. Horne and S. Nair. “Privacy-enhanced and fair matchmaking system – Applications and analysis of protocol, architecture, and performance,” in Proc. 16th International Conference on Security and Management (SAM), July 2017, pp. 161-167.
- D. Horne and S. Nair. “A feasibility evaluation of fair and privacy-enhanced matchmaking with identity linked wishes,” in Proc. 22nd Australasian Conference on Information Security and Privacy (ACISP), LNCS 10343, July 2017, pp. 422-434.
- L. Popokh, S. Nair, “Network Function Virtualization (NFV): Architectural and Information Model Framework”, Tech. Report, SMU AT&T Center for Virtualization, Dec. 2018
- D. Horne and S. Nair. “A New Privacy-Enhanced Technology for Fair Matchmaking with Identity Linked Wishes", IEEE Systems Journal (Accepted for publications, Nov. 2018).
- A. Eshmawi, and S. Nair. “The Roving Proxy Framework for SMS Spam and Phishing Detection”, Proceedings of The IEEE International conference on Computer Applications & Information Security (ICCAIS’2019).
- J. Collins, S. Nair, K. Prabhu. “Life on the Edge with 5G”, IEEE Computer Magazine, Aug. 2018 (submitted for publication)
- A. Omar, S. Nair. "OCCRA: Overt-Covert Challenge-Response Authentication Using Device-Centric Primitives", IEEE Transactions on Secure and Dependable Computing, Nov. 2018 (submitted for publication)
- L. Popokh, S. Nair, M. Odini. "Efficient Network Function Placement for Optimal Resource Utilization and Management”, The 5th IEEE International Conference on Network Softwarization, (submitted for publication).

Book Chapters:

- S. Nair, Encyclopedia of Cryptography and Security, (Associate Editor for OS Security (Henk C.A. van Tilborg, Sushil Jajodia Chief Editors), Springer, 2011
- S. Abu-Nimeh, D. Nappa, X. Wang and S. Nair, “Hardening Email Security via Bayesian Additive Regression Trees”, Chapter no. 9 in "Machine Learning", edited by Abdelhamid Mellouk and Abdennacer Chebira, ISBN 978-3-902613-56-1, pp. 185-206, February, 2009, I-Tech, Vienna, Austria.
- J. Tian, S. Nair, L. Huang, N, Alaeddine and M.F. Siok, "Developing Dependable Systems by Maximizing Component Diversity", In J. Dong, R. Paul and L.-J. Zhang, editors, *High Assurance Services Computing,* Springer-Verlag, 2009.
- M. Stephens, S. Nair, J. Abraham, “Distributed Computing Grids – Safety and Security”, In Security in Distributed, Grid, Mobile, and Pervasive Computing, Edited by Yang Xiao, Published by CRC Press, 2007, ISBN 0849379210, 9780849379215.

Patents:

- Suku Nair, G. Deprez, "Method and System for Decoupled Audio and Video Presentation", US Patent No. 6621502, Issued on Sep. 16, 2003
- Suku Nair, D. Horne, "Method and System for Privacy Preserving Disclosure of a Shared Identity Linked Secret", Provisional Patent Serial No. 62/412,627, Non-Provisional Application Submitted, 2018
- M. Rayes, Suku Nair, "Key-Exchange Protocol - A Matrix Approach", Disclosed for Patent Filing, Aug. 2018

Courses Taught:

<u>Undergraduate Courses:</u>

CSE 2340, Assembly Language Programming and Machine Organization
CSE 3381, Digital Logic Design
CSE 4381, Computer Architecture
CSE 5385, Microprocessor System Design
CSE 5381, Computer Architecture II
CSE 5344, Computer Networks and Distributed Computing II
CSE 5349, Network and Data Security
CSE 4344, Computer Networks and Distributed Computing I

<u>Graduate Courses:</u>

CSE 6380, Advanced Computer Architecture
CSE 8377, Fault-Tolerant Computing
CSE 7381, Computer Architecture II
CSE 8349, Advanced Data and Network Security
CSE 8344, Computer Networks
CSE 7344, Computer Networks and Distributed Computing II
CSE 7349, Network and Data Security
CSE 8394, Border and Transportation Security
CSE 7339, Computer Systems Security
CSE 8394, Nano-Security
CSE 8392, Software Defined Networks
CSE 8345, Software Centric Telecommunication Networks

Students:

<u>Past Ph.D. Graduates</u>

1. Bhanu Kapoor (Consultant, MIMASIC, Formerly with TI)
2. Mitch Thornton (Professor, SMU)
3. Krish Pillai (Associate. Professor, UPenn, Lockaven)
4. Candan Cankaya (Fujitsu)
5. Alkhalifa Zeyad (Founder CEO of Tech Company in Saudi Arabia)
6. Gheorghe Spiride (Ericsson)
7. K. Indiradevi (Cisco)
8. G. Deprez (Rockwell Collins)
9. M. Padmaraj (Bank of America)
10. T. Morris (Professor, University of Alabama)
11. S. Abu-Nimeh (Paypal)
12. M. Malaika (D.Eng.) (Cigital)
13. O. Al Ibrahim (Cigital)
14. Steve Papa (Lockheed Martin)
15. R. Al-Awadhi (Univ. in Kuwait)
16. R. Rafiqi (Google)
17. Ala Eshmawi (University in Saudi Arabia)
18. B. Ibrahim (University in Jordan)
19. S. Abraham (IBM)

Current Ph.D. Students:

1. S. Elliot
2. Dwight Horne
3. Leo Popokh
4. Matt Zaber
5. Derek Phanekem
6. Jeff Collins II
7. Justin Wilson
8. Mahesh Anjan
9. Michael Lefebvre
10. Starr Corbin
11. Cameron Keith
12. Yong Bekos

M. S. Graduates: More than 15 MS students

Professional Activities:

Program Committee Member:

- Associated Editor, IEEE Transactions on Dependable and Secure Computing (Jan. 2013 – 2018)
- Program Committee Member, 35th International Conference on Distributed Computing Systems, ICDCS'15, Jul. 2015
- International Conference on Computing, Networking and Communications, (ICNC 2013), San Diego, USA, January, 2013
- Program Committee Member, IEEE GLOBECOM 2011 - Communication & System Security
- Program Committee Member, IEEE/APWG Conference on Electronic Crime (eCrime2011), Nov. 2011
- Program Committee Co-Chair, IEEE/APWG Conference on Electronic Crime (eCrime2010), October 2010.
- Program Committee Member, 30th International Conference on Distributed Computing Systems (ICDCS-30), Genoa, Italy, June. 2010
- Program Committee Member, IEEE GLOBECOM 09, Honolulu, Hawaii, Dec. 2009.
- Technical Program Committee of the 7th IEEE International Workshop on the Design of Reliable Communication Networks (DRCN 2009).
- Program Committee Member, IEEE Computer and Communication Security Symposium, GLOBECOM 08, New Orleans.
- Program Committee, 10th IEEE High Assurance Systems Engineering Symposium (HASE 2007.
- Program Committee Member, IEEE Wireless Communications and Networking Conference, 2007.
- Member, IEEE Communications & Information Security Technical Committee (CISTC), April 2006 - Present
- Program Committee Member, IEEE Network Security Symposium, GLOBECOM 06
- Program Committee Member – The 4th ACS/IEEE International Conference on Computer Systems and Applications (AICCSA-06), April, 2006

- IEEE Network Security Symposium, GLOBECOM 05, St Louis, MO, Nov.28 – Dec. 2, 2005.
- IEEE Wirelesscom 2005, Hawaii, Jun. 13-16, 2005.
- The 3rd ACS/IEEE International Conference on Computer Systems and Applications (AICCSA-05), Cairo, Egypt, January 3-6, 2005.
- Associate Technical Editor, IEEE Communication Magazine, 1998 – 2005.
- 2nd International Workshop in Wireless Security Technologies (IWWST2004), 2004.
- The IEEE High Assurance System Engineering Workshop (HASE'97-99).
- The IEEE International Workshop on Evaluation Techniques for Dependable Systems, Oct. 1995.
- The IEEE, Computer Software and Applications Conference (COMPSAC'95), 1995.
- The IEEE, 11th International Conference on Distributed Computing Systems, 1991.

Organization:

- Moderator, Panel on Cyber Security Work Force Development, *Cyber Future Foundation*, President George Bush Institute, Dallas, TX, Oct, 2016-2018
- Organizer, SMU AT&T Center Workshop, Block Chain and Cloud – New Technology Patterns, Dec. 2017
- Moderator, Panel on Security of Smart Grids, Distributech Conference, San Antonio, Jan. 2014
- Session Chair, Healthcare Safety and Security, SPDS 2010, Dallas, TX
- Session Chair, 7th IEEE International Workshop on the Design of Reliable Communication Networks (DRCN 2009).
- Session Chair, Denial of Services Session, IEEE Globecom 2008, New Orleans
- Session Chair, 10th IEEE High Assurance Systems Engineering Symposium (HASE 2007), Dec. 2007
- Security Track Chair, The 3rd ACS/IEEE International Conference on Computer Systems and Applications (AICCSA-05), Cairo, Egypt, January 3-6, 2005
- General Chair, HACNet Workshop on "Harnessing Security: Ways, Means, and Technologies", Dec. 2003
- Moderator of panel on *Cyber Security*, DFW Homeland Security Alliance, Solutions Expo, Oct. 2003.
- Session Chair, IEEE International Conference on Pervasive Computing (PERCOM 03)
- Session Chair, International Conference on Security and Management (SAM02), June 2002.
- Session Chair, IEEE ASSET'00 Symposium, June 2000.
- Organized a Workshop on Fault-Tolerant Parallel and Distributed Systems, in conjunction with the IEEE Symposium on Parallel and Distributed Systems, Oct. 1995.
- Moderator of panel on *Software Fault Tolerance* at the IEEE Computer Software and Applications Conference, Oct. 1995.
- Panelist of session on *Trends in System Certification*, IEEE International Workshop on Evaluation Techniques for Dependable Systems, Oct. 1995.

Invited Talks:

- "Cognitive and Context Aware Systems, Invited Speaker, IEEE Metrocon, Nov. 2018
- "Building a Cyber Workforce – Opportunities and Challenges", Invited Speaker, SIM 2018 Cyber Security Virtual Summit, Oct. 2018
- "Programmable N/S Infrastructure for At-Scale Healthcare Analytics", Plenary Speaker, 2nd Illinois Health Data Analytics Summit, April 2018

- “Data is the New Oil” Panel Presentation, #Future Summit, Kochin, India, March 2018
- “Virtualization as a Pervasive Technology Enabler”, Invited Talk, NDIA Chapter (Lone Star Chapter) (National Defense Industrial Association)", Dec. 2017
- “Cognitive and Context Aware Security”, Fireside Chat Presentation, Accenture Tech Vision Lounge, June 2017
- “Code your way to Mars or to Prom”, Invited Talk, iCode Hackathon, April 2017
- “Big Data and Cyber Security”, Panel Presentation, Digital Business Summit in Chicago, IL, Dec. 2016
- “New Security Architecture for IoT”, Invited Talk, Missouri Science and Technology University, Nov. 2016
- “Compliance vs Competence: Cyber Security Management for Data Centers”, End-To-End Reliability: Mission Critical Facilities, Keynote Speaker, 7x24 Exchange, Research Triangle Park, NC, Mar. 2016
- “SDN Connecting the big dots for Healthcare – Big Data, Virtualization, and Assurance “, Keynote Speech, IEEE International Conference on Biomedical and Health Informatics, Las Vegas, Feb. 2016
- “Before the Attack – Cyber Security Program Management for Data Centers”, End-To-End Reliability: Mission Critical Facilities, Fall 2015 Conference, 7x24 Exchange, San Antonio, Nov. 2015
- “Security of Smart Appliances and Automobiles”, Intertek Inc., Jul. 2015
- “Software Defined Networks” Keynote Speech, ICCSC 2014, Trivandrum, India, Dec. 2014
- “Enterprise Security: Threat Landscape and Trends”, Bobby Jindal School of Management, University of Texas at Dallas, Oct. 2014
- “Cyber Security Career Opportunities”, 4th Annual Cyber Security Awareness Month Forum, Richland College, Richardson, TX, Oct. 2014
- “SDN Security”, Fujitsu Inc., Plano, TX, Oct. 2014
- “Cyber Security Research and Education for Future”, Cyber Intelligence Workshop, FBI, Dallas Chapter, Mar. 2014
- “Cyber Security: Currently Trending”, ISC8 Cyber Security Summit, Plano, Feb. 2014
- “Cyber Security Research at SMU: Past, Present and Future”, IBM, Atlanta, Nov. 2013
- “Research in Critical Infrastructure Protection”, CP&Y Summit on Critical Infrastructure Protection, Aug. 2013
- “Application Security”, Los Alamos National Laboratory, New Mexico, Apr. 2013
- “Industry Partnership in Cyber Security Research”, Baker Institute for Public Policy, Rice University, Houston, Mar. 2013
- “HACNet Labs: Leading Cyber Security Research at SMU”, Texas Tech University NSF-SFS Workshop on Educational Initiatives in Cyber-security for Critical Infrastructure, November 2012.
- Texas Cyber Consortium Summit, Texas A&M University-San Antonio, October 2012
- “Technical Perspective on Privacy”: Impact Symposium, Dedman Interdisciplinary Institute Inaugural Panel, Oct. 30, 2012
- “Phyber Security – Security for Cyber Physical Systems”, at Open Web Application Security Project (OWASP), June, 2011, Richardson, TX
- “Trustworthy Cyber-Physical Systems and Infrastructures (TCPSI)”, at NSF CyberCARD 2011, Workshop on "Cooperative Autonomous Resilient Defense in Cyberspace" January 27-28, 2011, Arlington, VA
- “Security Research in SMU HACNet Labs.” – at Lockheed, Rockwell Collins, Crane, Cp&Y, Revere, 2010

- “Security Engineering: Security Research in SMU HACNet Labs.”, CIO Roundtable, New Orleans, Sept. 2009
- “Application Security: Achilles’ Heel of Enterprise Security”, IEEE-FW Metrocon, Jun. 2009.
- “New Security Architecture for Nano-Sensors”, University of Oklahoma, OK, Jan. 2009
- “Healthcare Safety and Security”, University of Texas at Arlington, TX, Nov. 2008
- “Information Assurance Education, NSA Center of Academic Excellence”: Principal Investigator Meeting, Albuquerque, New Mexico, Oct. 2007
- “Computer and Network Systems Security”, Monterrey Tech, Mexico, June, 2007
- “Wireless Security”, Rockwell Collins, Richardson, TX, July 2006
- “Enterprise Security Planning”, L-3 Communications, Greenville, TX, June 2006
- “Nano-Security: A look under the hood”, National Institute of Standards and Technology (NIST), May 2005

<u>Proposal Review:</u>

- National Science Foundation (NSF)
- IEEE Engineering Initiation Proposal,
- Proposal to Korean Science and Technology Council

<u>Paper Review:</u>

IEEE Transactions on Dependable and Secure Computing, IEEE Transactions on Computers, IEEE Transactions on Computer-Aided Design of Circuits and Systems, IEEE Transactions on Parallel and Distributed Systems, IEEE Transactions on Reliability, Journal of Parallel and Distributed Systems, Journal of Electronic Testing: Theory and Applications, Journal for VLSI Signal Processing on Systolic Arrays, International Symposium on Fault-Tolerant Computing, International Symposium on Parallel Processing.

<u>Book Review:</u>

- Software Fault Tolerance (Editor: M. R. Lyu), John Wiley & Sons Publishers
- Software Fault Tolerance Hand Book, McGraw-Hill Publishers
- Comer, Computer Networks and Internets (3e), Prentice Hall Publishers
- D. Givon, Digital Principles and Design, First & Second Edition, McGraw-Hill Publishers
- The Handbook of Information Security (Editor: H. Bidgoli), John Wiley & Sons Publishers

<u>Membership:</u>

- IEEE, Upsilon Pi Epsilon

IP Litigation Support

April. 2016 – Dec. 2016 **Thompson and Knight LLP**
Case: Patent review, Claim Charts, Patent Re-examination
Project: Plaintiff Party in an Intellectual Property infringement case against major company.

Apr. 2013 – Mar. 2015 **Pillsbury Winthrop Shaw Pittman LLP**
Case: Patent review, Markman review, Claim Charts, Expert witness
Project: Defense Party in an Intellectual Property infringement case against competitor in wireless technology

Aug. 2011 – Jun. 2012 **Thompson and Knight LLP**
Case: Patent review, Claim Charts, Patent Re-examination including deposition with USPTO.
Project: Plaintiff Party in an Intellectual Property infringement case against major companies.

2010 **Thompson and Knight LLP**
Case: Patent review involving Two Major Companies
Project: Telecom Technology

2010 **Alston & Bird LLP**
Case: Expert witness, Claim Constructions, Claim Chart review
Project: Plaintiff Party in an Intellectual Property infringement case in server technology against major companies.

2007 **Wilmer Hale LLP**
Case: Patent review involving Two Major Telecom Companies
Project: Helped the team with expertise in Network Management and Administration Protocols and System Design.

2007 **Cooley Godward Kronish LLP**
Case: Patent review involving Internet Security Software Company
Project: Provided declaration in support of reexamining US patent

2006 **Patton Boggs LLP**
Case: Patent review involving Ericsson Inc.
Project: Helped the team with expertise in MPLS and VPLS

2005 **NKN Consulting**
Case: Intellectual Property infringement case involving Nokia and Kyocera
Project: Helped the team with expertise in cellular PCS and background Research

2003-04 **Moses and Singer**
Case: Plaintiff party in an Intellectual Property infringement case against major companies, such as Palm and Microsoft

EXHIBIT B

Information Reviewed in Support of My Opinions:

A. The Asserted Patents and their File Histories

B. Case Documents
1. Complaint
2. Defendant's Invalidity Contentions
3. Markman Order
4. Plaintiff's Infringement Contentions

B. Bate-Numbered Documents Produced
1. MWVZ00000001-MWVZ000002179
2. VZ_MW_0000001 – VZ_MW_0005205
3. CTIA Test Plan Wireless Device Over The Air Performance version 3.1
4. CTIA Test Plan Mobile Station Over The Air Performance version 3.7

C. Other
1. 3GPP TS 26.133
2. 3GPP TS TS 36.423 "Evolved Universal Terrestiral Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)"
3. 3GPP TS 36.300 Release 10
4. 3GPP TS 33.401
5. http://www.qtc.jp/3GPP/Specs/36423-800.pdf
6. 3GPP TS 25.3131 "UMTS Radio Resource Control (RRC) Control Specification"
7. http://www.eventhelix.com/lte/handover/LTE-X2-Handover-Messaging.pdf
8. http://www.3glteinfo.com/intra-lte-handover-using-x2-interface/
9. https://eventhelix.com/lte/handover/x2/lte-x2-handover-sequence-diagram.htm
10. https://www.netmanias.com/en/post/oneshot/5938/handover-lte/lte-x2-based-handover-s1-based-handover
11. Analysing X2 Handover in LTE/LTE-A http://www.eurecom.fr/en/publication/4854/download/comsys-publi-4854.pdf
12. https://www.slideshare.net/soksitha/lte-call-processing-and-handover
13. Alcatel-Lucent, Strategic White Paper, The LTE Network Architecture, A Comprehensive Tutorial (2009), originally published as a chapter in *LTE-The UMTS Long Term Evolution: From Theory to Practice* (Wiley 2009).